AD-A217 041

SAUGUS RIVER AND TRIBUTARIES

FLOOD DAMAGE REDUCTION STUDY

LYNN, MALDEN, REVERE AND
SAUGUS, MASSACHUSETTS

DESIGN AND COST ESTIMATES

APPENDIX D

Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

June 1989

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT UNLIMITED DISTRIBUTION
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Corps of Engineers-New England Div. — 6b. OFFICE SYMBOL (If applicable) CENED-PL	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) 424 Trapelo Road Waltham, Mass. 02254	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION — 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification) Saugus River and Tributaries Flood Damage Reduction Study: Lynn, Malden, Revere, and Saugus, Massachusetts, Estimates Appendix D; [Geotechnical Appendix E, Real Estate Appendix F]

12. PERSONAL AUTHOR(S)
Robert Hunt - Project Manager

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM Oct 85 TO Dec 89	06-89	192

16. SUPPLEMENTARY NOTATION Title Variation: Flood Damage Reduction, Volume 3, Appendix D - Design and Cost, E - Geotechnical, F - Real Estate

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
08	08	
13	02	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Floods; Embankments; Engineering Geology; Flood Control; Dredging; Flooding; Revetment

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This volume deals with detailed descriptions, plans and profiles and design considerations of the selected plan; coastal analysis of the shorefront; detailed project costs; scope and costs of engineering and design; scope and costs of operation and maintenance; and design and construction schedules. The Geotechnical section list the geotechnical considerations which are: a 1275 foot long floodgate structure across the mouth of the Saugus River, 8905 feet of dikes, walls and gates along Lynn Harbor, a 3420 foot long dike behind Revere Beach, 4050 feet walls, revetments, dunes at Point of Pines and a 10 acre clam flat basin. The Real Estate portion describes land and damages, temporary and permanent easements and costs of the selected plan, including the five floodgate alignments studied.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Timothy P. Hays	22b. TELEPHONE (Include Area Code) 617-647-8118 — 22c. OFFICE SYMBOL CENEDIM-SL

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE

SAUGUS RIVER AND TRIBUTARIES FLOOD DAMAGE REDUCTION STUDY
Lynn, Malden, Revere and Saugus, Massachusetts/Summary of Study Reports:

Main Report and Environmental Impact Statement/Report (EIS/EIR): Summarizes the coastal flooding problems in the study area and alternative solutions; describes the selected plan and implementation responsibilities of the selected plan; and identifies environmental resources in the study area and potential impacts of alternative solutions, as required by the Federal (NEPA) and state (MEPA) environmental processes.

Plan Formulation (Appendix A): Provides detailed information on the coastal flooding problem and the alternatives investigated; includes: sensitivity analyses on floodgate selection (including location and size of gates and sea level rise); optimization of plans; comparison of alternative measures to reduce impacts; and public concerns.

Hydrology and Hydraulics (Appendix B): Includes descriptions of: the tidal hydrology and hydrology of interior runoff in the study area, and of wave runup and seawall overtopping, interior flood stage frequencies, tide levels, flushing, currents, and sea level rise effects without and with the selected project for various gated openings.

Water Quality (Appendix C): Includes descriptions of existing water quality conditions in the estuary and explores potential changes associated with the selected plan.

Design and Costs (Appendix D): Includes: detailed descriptions, plans and profiles and design considerations of the selected plan; coastal analysis of the shorefront; detailed project costs; scope and costs of engineering and design; scope and costs of operation and maintenance; and design and construction schedules.

Geotechnical (Appendix E): Describes geotechnical and foundation conditions in the study area and the design of earth embankment structures in the selected plan.

Real Estate (Appendix F): Describes lands and damages, temporary and permanent easements and costs of the selected plan, including the five floodgate alignments studied.

Economics (Appendix G): Describes recurring and average annual damages and benefits in study area floodzones; economic analysis and optimization of alternative plans.

Socioeconomic (Appendix H): Describes the socioeconomic conditions in the study area and the affects of the selected plan on development in the floodplain and estuary.

Planning Correspondence (Appendix I): Includes all letters between community officials, agencies, organizations and the public and the Corps prior to agency and public review of the draft report.

Feasibility Study and EIS/EIR Comments and Responses (Appendix J): Includes all comments and Corps responses to letters received during agency and public review.

Environmental (Appendix K): Includes basic data from investigations of environmental resources in the study area and presents the Mitigation Incremental Analysis.

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DESIGN & COST ESTIMATES

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(Located at end of report)

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SAUGUS RIVER AND TRIBUTARIES

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1. SAUGUS RIVER FLOODGATE STRUCTURE

a. Purpose — Flood Damage Reduction

b. Location

State	Massachusetts
County	Suffolk and Essex
Cities	Lynn and Revere
River	Saugus River

c. Level of Protection

Frequency	Standard Project Northeaster (SPN)

d. Floodgate Structure

(1) Navigation Gate Structure

Type	Reinforced concrete
Length	148 feet
Width	95 feet
Height	33 feet from gate sill
Elevation, top	15 feet NGVD
Number of Gate	One (1)
Type of Gate	Miter (two (2) leaf)
Size of Gate	33 ft H x 100 ft W
Gate Sill Elevation	-18 feet NGVD

(2) Flushing Gate Structure

Type	Reinforced concrete
Length	588 feet
Width of Base	52 feet
Height of Base	29 feet from bottom of opening
Elevation, top	15 feet NGVD
Number of Gates	Ten (10)
Type of Gate	Tainter
Size of Gate	15 ft H x 50 ft W
Gate Opening	14 ft H x 50 ft W
Gate Sill Elevation	-14 feet NGVD

e. Concrete Gravity Wall/Access Road

Type	Mass concrete Reinforced concrete
Elevation, top	15 feet NGVD
Width, top	14 feet
Length, overall	280 feet
Height	Varies

f. Earth Dike

Type	Earth fill with stone slope protection
Elevation, Top of Dike	18 feet NGVD, Max (Design Top El. 15)
Top Width	16 feet
Length, overall	220 feet (with overlap)
Height	Varies
Upstream slope	IV on 3H
Downstream slope	IV on 3H

g. I-Wall & Ramp

(1) I-Wall

Type	Steel sheet pile with reinforced concrete cap
Elevation, top	15 feet NGVD
Top Width	1.5 feet
Length	100 feet
Height	Varies

(2) Ramp

Type	Earth fill with stone slope protection, gravel roadway
Elevation	Varies
Length	100 feet

h. Cofferdam (for construction)

(1) Ring Wall Cofferdam

Type	Steel sheet pile box girder
Size	210 feet inside diameter
Height	42.5 feet above Dredged River

h. Cofferdam (for construction) Continued

(2) Braced Cofferdam

Type	Steel sheet pile bracing
Width	60 feet (I-I of piling)
Length	Varies
Height	37 feet above Dredged River bottom

i. Principal Quantities

Dredging	114,200 cy
Concrete	24,000 cy
Concrete Piles	90,000 lf
Steel	3,000 ton
Miter Gate 33' x 100' (opening)	1 each
Tainter Gate 15' x 50' (opening)	10 each

2. LYNN HARBOR: DIKES AND WALLS

a. Purpose — Flood damage reduction

b. Location

State	Massachusetts
County	Essex
City	Lynn

c. Level of Protection

Frequency	SPN

d. Dikes

Type	Impervious fill, with underlayer and stone slope protection
Elevation, top	17.0 ft NGVD (1800 lf) and 15.0 ft NGVD (2600 lf)
Width, top	12 feet
Length, overall	4400 feet
Height	17 to 22 feet above sand flats
Area Displaced	8 acres
Seaward Slope	IV on 2H
Landside Slope	IV on 2H

e. <u>Steel Sheet Pile Wall</u>

Type	Steel sheet piling
Elevation, top	15.0 feet NGVD
Length	1435 feet
Height	5.0 feet above landside

f. <u>Steel Sheet Pile Caps</u>

Type	Steel sheet piling
Elevation, top	15 feet NGVD
Length, overall	1100 feet
Height	5 feet above existing SSP wall

g. <u>I-Wall</u>

Type	Reinforced concrete wall on steel sheet piling
Elevation, top	14.0 feet NGVD
Length	780 feet
Width, top	1.5 feet concrete wall
Height	6 feet exposed

h. <u>Gravity Wall</u>

Type	Mass concrete
Elevation, top	14.0 feet NGVD
Length	1080 feet
Width, top	1 foot
Height	1 foot exposed

i. <u>T-Wall</u>

Type	Reinforced concrete
Elevation, top	14 feet NGVD
Length	100 feet
Height	14 feet exposed

j. <u>Interior Drainage</u>

Type	Gravity
Pipe Size	12", 18", 24",36", 48", 72"and 84"
Pipe Type	Reinforced concrete
Length, overall	1650 feet
Gate Size	84, 72, 48, 36 and 18 inch
Gate Type	Sluice

k. "Heritage Park" Storm Drain

Type	Gravity
Location	Heritage Park
Size	72 inch
Gate Type	Sluice

l. Principal Quantities

Excavation	36,700 cy
Random Fill	13,300 cy
Compacted Random Fill	13,300 cy
Dumped Granular Fill	46,000 cy
Stone Protection	21,400 cy
SSP PZ - 27	165 tons
SSP PZ - 40	543 tons

3. POINT OF PINES

a. Purpose — Flood damage reduction

b. Location

State	Massachusetts
County	Suffolk
City	Revere

c. Level of Protection

Frequency	100 year

d. Stone Revetment

Type	Armor stone face, stone underlayer and gravel bedding
Elevation, top	16.0 ft NGVD (870 lf) 14.5 ft NGVD (450 lf) 14.0 ft NGVD (1600 lf) 13.2 ft NGVD (230 lf)
Width, top	10 to 22 feet
Length, overall	3,150 feet
Height	14.5 - 16.0 feet above existing beach
Area Displaced	5 acres
Seaward Slope	IV on 3H
Access Steps	Various locations

e. Concrete T-Wall

Type	Reinforced concrete
Elevation, top	14 to 15.0 feet NGVD
Width, top	1.0 feet
Length	700 feet
Height, Maximum	10.0 feet exposed beach side
Vehicular Gate	10.0 feet wide, stop log
Access Steps	1 each

f. Dunes (Re-tore)

Type	Sand
Elevation, top	14.0 to 16.0 feet NGVD
Length	1600 feet
Crossovers	end of streets

g. Concrete Cap

Type	Reinforced concrete
Elevation, top	14.0 feet NGVD
Length	200 lf
Width, top	5 feet
Height,	1.7 feet above existing wall

h. Beach Replacement	Sand Top El. 6.0 ft NGVD Top Width 30 feet

i. Principal Quantities

Armor Stone	35,700 cy
Underlayer Stone	20,100 cy
Gravel Bedding	10,140 cy
Excavation	73,300 cy
Sand Fill	42,200 cy (includes 36,000 reused)

4. REVERE BEACH PARK DIKE

a. Purpose	Flood damage reduction

b. Location

State	Massachusetts
County	Suffolk
City	Revere

c. Level of Protection

Frequency	SPN

d. Dike

Type	Stone slope protection, gravel bedding and impervious core
Elevation, top	23 feet NGVD
Width, top	10 feet
Length	3400 feet
Height	15 feet
Area Displaced	12.0 acres
Seaward Slope	IV on 2.5H
Landside Slope	IV on 2.5H
Vehicle Access Gate	1 - Stop Log Structure

e. Concrete Retaining Wall

Type	Mass concrete
Elevation, top	20 & 23 feet NGVD (Max.)
Width, top	2.0 feet
Length, overall	1200 feet
Height	Varies

f. Ramps (roadway & walkways)

Type	Earth berm, paved surface
Elevation, top	20 feet NGVD
Length	900 foot Total

g. Stop-Log

Type	Reinforced concrete and Mass concrete/Timber Log
Elevation	22 feet NGVD
Width	30 feet
Height	10 feet

h. Flood Walls (North and South

Type	Steel sheet pile with reinforced concrete cap
Elevation, top	22 feet NGVD
Width, top	1.5 feet
Length, overall	70 feet
Height	10 feet, exposed

i. Interior Drainage

Type	6'x6' Sluice Gate (Sales Creek) Electric, Mounted on concrete Headwall of 60" culvert

j. Principal Quantities

Excavation General	19,800 cy
Stone Protection	6,400 cy
Compacted Random Fill	54,300 cy
Topsoil Seeded	38,700 cy
Random Fill	57,000 cy
Mass Concrete	2,100 cy
Gravel Bedding	6,000 cy

5. PONDING AREA AND WALL

a. Purpose — Flood Water Storage

b. Location

State	MA
County	Suffolk
City	Revere

c. Type — Concrete Gravity Wall

Elevation, top	12-16 ft NGVD
Length	500 feet
Height	3-7 feet

d. Principal Quantities

Excavation	750 cy
Compacted Random Fill	400 cy
Gravel Bedding	125 cy
Topsoil and Seed	500 sy
Concrete	525 cy

6. MITIGATION CLAM FLAT AREA

a. Purpose — Mitigation

b. Location

State	MA
County	Suffolk
City	Revere

c. Area

Clam Flats	10 Acres
Marsh Grass	2.5 Acres
Buffer Zone	0.5 Acres
Berm	1 Acre

d. Clam Flat Basin

Top Elevation	9 ft NGVD
Bottom Elevation	-4 ft NGVD

e. Berm

Top Elevation	11 ft NGVD
Bottom Elevation	9 ft NGVD
Top Width	10 feet
Side Slopes	1 on 3

f. Principal Quantities

Excavation	
Salty Sand	110,000 cy (Stockpile 35,000 cy)
Clean Sand	76,000 cy (Stockpile 20,000 cy)
Peat	4,000 cy (To disposal Site)
Berm - Sand Fill	3,000 cy

7. ESTUARY STORAGE AREA

a. Purpose — Flood Water Storage

b. Location

State	MA
County	Suffolk and Essex
Community	Lynn, Revere and Saugus

c. Storage Capacity — 5400 Acre - feet

d. Area — 1500 to 1600 Acres

e. Storage Area — El. 2 to 8 ft NGVD

8. MAINTAIN EXISTING REVERE BEACH

a. Purpose — Flood Damage Reduction

b. Location

State	MA
County	Suffolk
City	Revere

c. Seawall Length — 14,540 Feet
Seawall Height — Varies

d. Beach Length — 13,000 Feet
Beach Height and Slope — Varies

B. SELECTED PLAN

The selected plan consists of dikes, walls, revetments, dunes, beach reconstruction and a floodgate structure. The floodgate structure includes a navigation and 10 flushing gates housed in a mass and reinforced concrete structure located at the mouth of the Saugus River. The project extends north approximately 8900 feet along the Lynn shoreline of Lynn Harbor and south about 20,000 feet along the Point of Pines and Revere Beach areas of Revere (see Plate D1). As formulated the project provides protection to the shoreline and backshore areas of Revere, Lynn, Malden and Saugus from a point just north of Elliot Circle in Revere to the Lynn Harbor area of Lynn. Included in this area are 5000 buildings and General Electric's "Lynn" plant which manufactures jet engines and steam turbine generators for the U.S. Government.

C. DESCRIPTION OF PROPOSED STRUCTURES AND IMPROVEMENTS

1. GENERAL

The selected plan shown on Plate D1, is based around a floodgate structure approximately 1300 feet in length located at the mouth of the Saugus River. This structure contains a navigation gate and "flushing gates" to facilitate boat traffic and tidal flows. At its northern or Lynn, MA end this structure ties into a stone faced dike. The dike extends northward along the Lynn Harbor shorefront approximately 3100 feet. At that point the protection changes to a steel sheet pile wall and continues northward approximately 3100 feet where it ties into a second stone faced dike. This second dike continues along the shoreline for about 1100 feet before tying into a concrete floodwall. The floodwall, a combination of gravity wall, I-wall and T-wall sections, extends northward approximately 1400 feet and ties into existing high ground at the northern end of the project opposite Heritage Park.

At its southern or Revere, MA end, the floodgate structure ties into a concrete floodwall which extends about 700 feet along the Saugus River to the "Point" at Point of Pines. From this location a concrete cap, about 200 feet in length, is constructed on top of an existing wall to raise it to the required level of protection. From the end of the existing wall the line of protection extends southward along the shorefront to Carey Circle a distance of about 3150 feet. Within this reach the project consists of a stone faced revetment fronted by a sand dune and beach on the waterside which reduces wave run-up and overtopping.

From Carey Circle southerly to Elliot Circle, a distance of about 14,000 feet, the project consists of maintaining the existing beach and seawall along Revere Beach, supplemented in one area by a shoreward dike located between Beach Street and Revere Street and following, or paralleling, the Boulevard along the existing beach. This dike, about 3400 feet in length and centered about 150 feet shoreward of the existing seawall, provides protection against wave overtopping and flooding of lowlying areas behind the beach.

Additional components of the project include: a sluice gate and structure located at the Heritage Park area of Lynn, MA for a 72 inch storm drain; a 6' x 6' sluice gate structure on Sales Creek located near the intersection of Revere Beach Parkway and North Shore Road near the Suffolk Downs racetrack, and a sandbag closure across the MBTA rail line beneath the Beach Street overpass. The features are required to prevent tidal inflows from circumventing the line of protection and entering into the protected area. In addition a ponding area, located toward the northern end of Revere Beach, will act as a storage area to collect runoff from wave overtopping. The ponding area will be located just north of Sea View Condos and will include a concrete wall 500 feet long. The wall follows an old narrow gauge railroad embankment between North Shore Road and Revere Beach Boulevard. Temporary sandbag closures are needed across the Boulevard at the wall and at Carey Circle to direct water toward the ponding area.

A mitigation area includes excavating a tidal basin underneath about 14 acres of the existing I-95 sandfill near Copeland Circle. About 10 acres would be seeded with clams and 3 acres with upland or marsh grass. A protective berm covering one acre is needed around the basin.

For flood water storage, protection of 5400 acre-feet of storage is required in the estuary. Also, the existing Revere Beach and seawall must be maintained to continue to reduce damages.

2. SAUGUS RIVER FLOODGATE STRUCTURE

The Saugus River Flood Gate structure is sited at the mouth of the Saugus River where it enters Broad Sound (See Plate D2A). The overall length of the structure is 1275 feet. The main elements of the structure consist of one navigation gate, ten "flushing" gates, a stone faced dike and concrete gravity and "I" walls shown on Plates D2 to D4. The navigation gate has an overall width of 100 feet and is centered upon the existing Saugus River navigation channel. The width of the gate opening is sized to allow safe passage of vessels of the size currently utilizing the channel and equals the navigation opening of the General Edwards highway bridge (Rt.1A) located 700 feet upstream on the Saugus River. Closure of the gate opening is by a miter gate consisting of 33 foot high by 100 foot wide. The sill elevation of the structure is at -18.0 feet NGVD, matching the bottom elevation of the existing navigation channel. To the south and north of the navigation gate are respectively one (1) and nine (9) each flushing gates. These gates are designed to allow tidal flows to occur as close to the existing pre-construction conditions as possible and minimize any increase in flow velocity that would occur as a result of a decrease in waterway area. Each gate opening is 14 feet high by 50 feet wide. Gate sill elevations are set at -14.0 feet NGVD. A detailed description of the navigation and flushing gates is presented in later paragraphs. The river would be dredged to Elevation -14 ft NGVD, as shown on Plate D2A.

At the northern end of the flushing gates, the structure transitions to a 140 foot long gravity wall which ties into the proposed Lynn Harbor Dike. The top of this gravity wall is set at 15 feet NGVD. At it's southern end the floodgate structure transitions to another concrete gravity wall, approximately 140 feet long, which ties into a stone faced dike. This dike, 220 feet long (165' plus 55' overlap of the gravity and I-Wall), ties into a 100 foot long steel sheet pile concrete capped floodwall which in turn ties into existing ground and a new concrete T-Wall at the Point of Pines area of Revere.

Access to the floodgate structure is via two roads, one from Lynnway and an access road and parking area on the north or Lynn side and the other from Point of Pines at Rice Avenue. These roads provide access to the floodgate structure both for operational and maintenance requirements. The roads are secured by gates to provide against unauthorized entry onto the structure. To discourage boats and swimmers from passing through the tainter gates, floating log booms and other measures would be investigated during design.

2A. GATE DESIGN

Several different gate designs were investigated for both the navigation gate and the flushing gates.

Three different types of gates were looked at for the navigation opening. They were: sector gates, miter gates and drum gates. A bottom hinged flap gate, similar to the one used at the Stamford CT. Hurricane Protection Project, was not investigated due to various problems that have been experienced using that design. The drum gate was not evaluated in detail since its mechanical first cost was the same as the miter gate, and it required much more excavation. The drum gate structure would be located below the river bottom, almost 40 feet deeper than the miter gate. There are also concerns on the design of a cofferdam for drum gates retarding flows in the river. The sector gate and miter gate were evaluated for the navigation gate. The miter gate was selected due to its much lower cost than the sector gate.

Several different alternatives were also looked at for the "flushing" gates. These included: sluice gates, flap gates, roller gates, drum gates and tainter gates. All flushing gate alternatives, except the tainter gates, were considered to be of a corrosion resistant design since they would be located within the normal tide range. The tainter gate would be situated such that the trunnion would be out of the tide range the majority of the time. The sluice and flap gates would be manufactured of a 2 percent cast iron. Roller gates would be manufactured from stainless steel. All embedded portions of the gates would be made from Ni-resist cast iron. For this study, it was assumed that sluice, flap, and roller type flushing gates would be hydraulically operated to minimize the electric service required at the site. The tainter gates would be operated by electric hoist.

2B. DESIGN OF FLOODGATE STRUCTURE

a. Miter Gate Abutments. Layout of the concrete abutments for the miter (navigation) gate was predicted by the following controls:

(1) The top elevation of the abutments is set at elevation 15.0 feet NGVD, based on a SPN stillwater level at elevation 12.0 feet plus three (3) feet of freeboard to preclude significant wave overtopping.

(2) The still is at elevation -18.0 feet, matching the elevation of the existing channel bottom.

(3) The width of the navigation opening is 100 feet, the same as the existing width of the navigation opening under the General Edwards Bridge.

The preceding controls combined with the guidance on basic dimensions presented in EM 1110-2-2703, "Lock Gates and Operating Equipment," were used to formulate a conceptual design for the abutments. No structural design calculations for the abutments were prepared for this study.

Since the foundation materials for the tidal floodgate structures are highly compressible, the structures will be supported by piles driven to bedrock. An assumed pile layout for the abutments was used to develop quantities for this study.

b. Tainter Gate Monoliths. Concrete monoliths for the ten (10) tainter (flushing gates were detailed based on the following controls:

(1) The top elevation is set at elevation 15.0 feet NGVD.

(2) The sill is set at elevation -14.0 feet for hydraulic requirements.

(3) The trunnion is set at elevation 6.0 feet to be out of the tide range (mean high water is at elevation 5.0 feet) a majority of the time.

Preliminary structural calculations were prepared to verify the reasonableness of the proposed concrete monolith and to develop a foundation pile layout. Both steel and prestressed concrete foundation piles were analyzed and determined to be suitable. Based on discussions with local pile driving contractors, it appears that prestressed concrete piles will be more economical. Accordingly, cost estimates for all the tidal floodgate structures were developed assuming the use of prestressed concrete foundation piles.

c. Gravity Walls. The concrete gravity walls at both ends of the tidal floodgate have a top elevation of 15.0 feet NGVD and a stepped bottom elevation assumed to be located four (4) feet below the existing mudline. A wall cross section was developed by assuming the base width of wall to be approximately equal to 75 percent of the exposed wall height. An assumed layout of foundation piles for the gravity walls was used to develop quantities for this study.

d. I-Wall. An I-wall, consisting of PZ-27 steel sheet piles with a reinforced concrete cap, was adopted to form the closure between the tidal floodgate dike and the concrete floodwall at the Point of Pines area of Revere. The proposed wall is of the type typically used on Corps' projects where a transition between a dike and concrete structure must be made. However, preliminary civil layout indicates that the height of fill to be retained by this wall is the maximum for which an I-wall would be structurally adequate. The suitability of the I-wall will be assessed during the design phase when the layout of project features is refined. High cost estimate contingencies have been included to reflect this uncertainty.

e. Cofferdams. A scheme using a ring cofferdam, within which the navigation gate would be constructed, and a braced cofferdam, within which the flushing gates and gravity walls would be constructed, is preliminarily judged to be the most economical means of de-watering. The ring cofferdam was patterned similar to the cofferdam design prepared by the New Orleans District, Corps of Engineers, for the Larose Floodgate Bypass Channel located in Grand Isle, Louisiana. The proposed ring cofferdam consists of a cell, 210 feet in diameter, formed with PZ-27 steel sheet piles and internally braced with circular steel box girders at several levels. A preliminary analysis was performed to determine size (stillwater elevation 9.1 feet NGVD plus a 2.5 foot wave). The braced cofferdam consists of vertical steel sheet piling which is internally braced by a system of wales and struts. Preliminary structural analysis was performed to determine the size and required penetration of the sheet piles, and to size internal bracing members. The braced cofferdam was designed to withstand a 10 year event as described above.

f. Sea Level Rise. For this study, the structural features (miter gate abutments, tainter gate monoliths, gravity walls, and I-wall) of the floodgate have been designed for existing tidal conditions, i.e., SPN stillwater elevation of 12.0 feet NGVD plus a 2.5 foot wave. Historical sea level rise, approximately one (1) foot per century, is not expected to cause any damage to structural features of the tidal floodgate. During the design phase, stability of all structural features will be checked for tidal conditions associated with the historic rate of sea level rise.

Accelerated sea level rise, at the maximum estimated rate of four (4) feet per century, has not been addressed in the proposed designs or construction cost estimates presented herein. Although no effort was made to incorporate design features to facilitate future changes, retrofitting of the proposed structural features appears feasible.

2C. EARTH DIKE

The Geotechnical Appendix explains the design of the earth dike for the floodgate structure. It also includes revetments and dikes used for other project features.

3. LYNN HARBOR - DIKES AND WALLS

Beginning at the northern end of the floodgate structure, the protection consists of a series of stone faced revetments or dikes, steel sheet piling walls and concrete walls. The overall length of the protection is about 8900 feet, and extends from the floodgate structure, at the mouth of the Saugus River, northward along the Lynn shoreline to a point at the west corner of the Heritage Park area of Lynn, where it ties into existing high ground. Plans and sections are shown on Plates D5 to D8.

At various locations along the Lynn (and Revere) shorefronts sandbag closures are included. These closures would be evaluated in final design for stop log closures and/or road raising.

From the floodgate structure, a stone-faced dike extends northward 3300 feet. The top of the first 1800 feet of the dike (Reach "B") is set at elevation 17.0 feet NGVD and is 12 feet in width (See Plate D5). The waterside face of the dike is sloped IV on 2H with a three layer stone protection system consisting of 3 feet of stone protection over a 12 inch stone bedding layer placed over a 12 inch layer of gravel bedding. At the top of the dike the stone protection is reduced to a thickness of 2.5 feet and extends at this thickness across the top of the dike ending at the top of the landside slope. The landside face is also on a IV to 2H slope and is comprised of the 12 inch stone bedding layer over the 12 inch gravel bedding layer.

At the northern end of the above section, the dike transitions to a reduced section. This reduced section continues for a distance of 1500 feet (Reach "C") (See Plate D6). The section is similar to the first 1800 feet except that the top elevation is set at 15.0 feet NGVD and the stone protection is reduced to two layers in thickness. On the water side slope the protection consists of a 2 foot stone protection layer over a 12 inch gravel bedding layer. The stone protection reduces in thickness to 1.5 feet at the top of the dike and continues across the top to the landside edge. The 12 inch gravel bedding layer continues down the landside face of the dike on a IV on 2H slope (See Plate D8).

Beginning at the end of the dike the protection consists of a series of walls of varying types extending a distance of about 3100 feet (Reach "D") as shown on Plate D6. This reach begins with a steel sheet pile wall consisting of PZ-27 steel sheet piles (SSP) with a top elevation set at 15 feet NGVD. The wall is constructed with steel tie backs located 10 feet on center. The wall extends along the alignment of the existing bulkhead to a point at the southerly corner of the existing Gas Wharf Inlet, a distance of approximately 1035 feet. A 30 foot long stoplog structure, 190 feet south of the end of this wall, is provided for the existing EDIC Pier (not shown).

The SSP-Wall ties into an existing sheet pile wall along the southside of the Inlet that will be modified with a 5 foot high PZ-40 SSP extension added to the top of this existing wall in order to bring it to the required level of protection. This wall extends for a distance of 280 feet and includes a timber platform for visibility in off/on loading vessels. At its end, the wall ties into an existing concrete building. The building is one of two floodproofed concrete structures that will form a part of the line of protection. A 30 foot long PZ-40 SSP-Wall will connect the two buildings in order to complete the protection. From the northerly side of the second flood-proofed building there is a 30 foot long stoplog structure, a short distance from this building, which would provide access for an existing boat crane. From this point there is a 370 foot long PZ-40 SSP-Wall which would replace an existing retaining wall. This new wall would tie into an existing SSP-Wall located outside the limits of the spill containment dike of the Boston Gas Company. The existing SSP-Wall has a top elevation of 10 feet NGVD. To bring this up to the required elevation of 15 feet NGVD, a 5 foot SSP (PZ-40) extension would be welded to the existing pile wall.

This wall extends northward 630 feet to the south corner of the Lynn Harbor Marine boat ramp entrance channel. At the entrance channel, the protection changes to a concrete I-wall. This I-wall, which is set on top of PZ-27 SSP, extends for 520 feet. Along the wall is a 40 foot stoplog structure and a 60 inch pipe closure structure and sluice gate. Beginning at the end of the I-wall the protection consists of a 5 foot SSP (PZ-40) extension which is welded to the top of an existing SSP-Wall. This extends northward for a distance of 190 feet and ties into a new stone faced dike (Reach "E").

This new dike replaces an existing stone revetment. The new dike section is the similar to the dike section located in Reach "C" and described above. This dike is 1100 feet long and ties into a Lynn Harbor Development Project.

The ground level for the development is being filled to 13± feet NGVD (maximum height may reach 18 ft NGVD). In order to provide the SPN level of protection (14 ft NGVD) a one foot high concrete gravity wall, approximately 1080 feet long, would be built behind the developers revetment.

A concrete cap I-wall, 5 feet high and 210 feet long, would extend northward from the end of the gravity wall to a point where there are 3 existing storm drains, one each 48 inches, 84 inches, and 72 inches in diameter. To prevent infiltration of flow during high storm tides sluice gate closures may be used for these drains. During this feasibility study minimal analysis of these storm and sewer drain systems was done. Detailed analysis will be undertaken during the design phase. These sluice gates will be mounted on a concrete T-wall. This T-wall is 100 feet long, with a top elevation set at 14 feet NGVD, and will extend from the end of the I-wall northwesterly to meet high ground near Heritage Park. Depending on the exact location of the El.14 contour, a sandbag closure to the Lynn Way median wall may be required (See Plate D7) within the freeboard range. In addition to the previously referenced storm drains there is another 72 inch storm drain at Heritage Park. This drain, while outside of the limits of the new construction may require a sluice gate and gate structure to prevent inflows from high storm tides.

In addition to the sluice gates at the northern end of the project, modifications to the existing storm drains located behind the proposed stone faced dike at the southern end of Lynn Harbor along Riley Way (Reaches "B" and "C") are also required. Existing storm drains discharge into the harbor at various locations along the existing wooden bulkhead that is to be removed. These drains will have to be rerouted and collected behind the new dike. About 980 feet north of Riley Way a new storm drain will intercept and collect storm water flows from five (5) existing drains. This new drain flows southward to meet another existing 24 inch concrete storm drain. Another 12 inch drain 470 feet south of the existing 24 inch drain will be rerouted to flow northward to a new junction manhole which will be built at the intersection of these drain pipes. From this point the drain, a 36 inch concrete pipe, will discharge through a sluice gate structure, set in the dike, into the harbor.

In addition, there are two 60 inch sewer outfalls that may need to be closed during high storm tides. This would be accomplished by two 60 inch sluice gate closures to be installed, one on each pipe.

At the northern end of Reach "C" an existing 12 inch drain outfall located 230 feet from the north corner of Riley Way will be removed and the drain rerouted. The new 12 inch RCP pipe will extend 160 feet toward the south and will discharge into an existing manhole. This manhole discharges into an existing 12 inch drain out fall at the north corner of Riley Way. This outfall will be replaced with an 18 inch RCP pipe and sluice gate closure.

4. POINT OF PINES - REVETMENT, DUNES AND WALLS

Beginning at the southern end of the floodgate structure, at the Point of Pines area of Revere, the protection consists of; a concrete T-Wall, a concrete cap placed on an existing seawall, a stone revetment buried beneath rehabilitated and stabilized sand dunes and stone revetments fronted with a reconstructed beach. The level of protection for the Point of Pines area is 100 years. The structures would be designed to withstand an SPN storm without failing. Plans and sections are shown on Plate D9 and D10.

Beginning at the southerly end of the floodgate structure is a concrete T-Wall. This wall extends eastward along the Saugus River about 700 feet to the "point" of Point of Pines (Reach "F"). This wall runs along the alignment of the existing precast sea wall structure which would be removed. Access for maintenance of the existing beach would be provided by a 10 foot wide stoplog structure and a stepped crossover.

From the "point" of Point of Pines the protection would continue southward along Broad Sound toward Carey Circle. The first 200 feet (Reach "E") will consist of a reinforced concrete cap placed on top of an existing seawall. This will raise the seawall to the required level of protection.

Continuing south of this wall would be a stone revetment buried under rehabilitated sand dunes. The top of the revetment will be set at elevation 14.0. The revetment section has a 3.5 feet thick two layer armor stone protection. The seaward face slopes 1V on 3H down to elevation 5.0 ft NGVD (See section on plate D10). Beneath the armor stone there is an 18 inch thick stone underlayer placed on an 18 inch gravel bedding layer. The existing sand dunes and beach will be restored and stabilized using sand fill and selective planting of beach grass to stabilize the area. In addition a "sand" catchment fence would be placed along the dune crest to assure the development and continuity of the system and to minimize foot and vehicular traffic over the sand dunes. Access to the beach will be provided by wooden ramps, or walkways, constructed over the dunes. These wooden ramps would be located at various sites as indicated on the plans.

The remaining "Point of Pines" protection (Reaches A, B, C and D) would consist of a stone revetment extending from Carey Circle northward connecting with Reach E. The proposed revetment would start with a transition section in Reach A adjacent to Carey Circle and continue northward toward Reach E. In Reach A, the top elevation would begin at 13.2 feet NGVD and gradually increase to 16.0 feet NGVD and continue to station 0+00, as shown on Plate D10. This top of protection elevation would remain the same up to station 10+00. At this location the top elevation would decrease to 14.5 feet NGVD and continue to station 14+00. Beginning at station 14+00 is a transition section between this rock revetment and the previously described revetment buried beneath the sand dunes at Reach "E".

The revetment section in Reach A to D consists of an 8 foot thick, double layer of armor stone sloping 1V on 3H down to the level of the existing beach. The toe of the slope is keyed into the beach sand. Beneath the armor stone is a 5 foot thick stone underlayer and an 18 inch thick layer of gravel bedding. Fronting this stone revetment is a reconstructed beach from surplus sand excavated from under the dunes for the revetment. The beach would extend from "Reach B" through part of "Reach E". Beginning at the seaward face of the revetment the beach consists of a 30 foot wide level berm set at elevation 6.0 feet NGVD. From the seaward edge of the berm the sand slopes 1V on 12H down to the level of the existing beach. (See Plate D10 Section) Beach access would be provided by walkways over the protection to the beach area. Depending on the suitability of sand dredged for the floodgates, the maximum beach could be raised to El. 13, 50 foot berm, in lieu of hauling the dredged material to the disposal area. Also in design, modelling may show a built-up beach to be as effective and in lieu of a revetment.

5. <u>REVERE BEACH PARK DIKE</u>

The Revere Beach Park Dike is located between Revere Street and Beach Street in Revere. The top elevation of the dike is set at 23.0 feet NGVD. The centerline of the dike is set 150 feet shoreward of the existing Revere Beach seawall. The dike serves to prevent wave overtopping and flooding of the low lying areas located behind the beach. Plans and sections are shown on Plate D11.

The dike begins at Revere Street and extends southward 3400 feet to a point just north of Beach Street. At the northern end of the dike the intersection of Revere Street and Revere Beach Boulevard is raised to the design interior ponding level elevation of 20.0 feet NGVD. The seaward edge of the raised section of Revere Beach Boulevard is supported by a concrete retaining wall. Freeboard is provided by the use of sandbags from the top of dike to the north pavilion (#6) seawall during high storm tides. At pavilion #6 the Beach lies from El. 10 to 15 and overtopping of the El. 21.1 seawall is not a problem. From Revere Street the protection continues southward, following the alignment of Ocean Avenue which is located immediately behind the dike. The top of the dike is 10 feet wide. The seaward face extends on a flat slope from the top of the dike to the landside sidewalk or retaining wall of the revised alignment of Revere Beach Boulevard. The realignment of Revere Beach Boulevard is being accomplished as part of an MDC Master Plan for improving the Revere Beach area and is not a part of the flood control plan. The slope of the seaward face varies and is surfaced with topsoil creating a park like environment. Buried beneath this seaward slope is a stone revetment. This revetment, located immediately seaward of the dike centerline, is sloped IV on 2.5H and consists of an 18 inch thick layer of stone over 12 inches of gravel bedding. An impervious core about 10 feet in width is located immediately behind this stone protection. On the landward side of the dike the fill is placed on a IV to 2.5H slope and consists of topsoil placed over random fill.

At a point 1420 feet south of Revere Street just north of Shawmut Avenue Extension the dike ends. A concrete retaining wall provides support for the end of the dike. Extending southward from, and tied into the retaining wall is a concrete floodwall. This wall, 90 feet long overall ties into the existing MDC Police Station. The wall also has a 30 foot wide stoplog opening which provides access along Shawmut Avenue Extension. The seaward face of the MDC Police Station has been floodproofed up to the design water level and will be a part of the line of protection. Continuing south from the police station, there is a concrete floodwall tied into the station. This wall is 10 feet in length and is tied into another retaining wall which forms the end of another dike. This dike, similar to the section described above, continues southward for 2000 feet to a point immediately north of Beach Street. At this point the dike alignment turns toward Revere Beach, crosses Revere Beach Boulevard and ends at a retaining wall located on the alignment of the existing seawall Access over this dike is provided by ramping Revere Beach Boulevard over the crest of the dike. In order to do this it is necessary to raise Revere Beach Boulevard starting north of Beach Street located just south of the dike. The elevation at the top of the ramp is 20.0 ft NGVD. Sand bags will be used to provide freeboard closure between the dike and new seawall. The new seawall or retaining wall ties into the Pavilion #2 seawall with a top El. of 18.3. Overtopping of Pavilion #2's seawall is not a problem with the existing beach between El. 11 to 15. A temporary sand bag closure is required across the MBTA tracks under Beach Street to prevent flood levels above the 100 year level from entering behind the dike south of Beach Street. A sluice gate (6' x 6'), electrically operated, is required on the Sales Creek 60 inch diameter culvert to prevent floodwaters, which overtop Bennington Street into Suffolk Downs, from entering the Garfield School area. The sluice gate would be mounted on the concrete headwall on the Suffolk Downs end of the culvert.

6. PONDING AREA AND WALL

The protected ponding area is located along Rt. 1A behind the buildings along Revere Beach Boulevard at the north end of Revere Beach. At the south end of the ponding area is the old narrow gage railroad embankment. The ponding area ends behind buildings opposite Carey Circle at the north end of Revere Beach. To contain water in the ponding area and direct its flow towards the estuary a concrete wall and three temporary closures are needed, shown on Plate D21 and D22.

The concrete gravity wall starts at the Boulevard sidewalk at a height of about three feet above grade (top of wall El. 16) and replaces the existing retaining wall along the north side of Sea View Towers driveway. The top elevation varies down the slope maintaining a height of about 3 feet until the top of wall reaches El. 12.

The top of wall remains at El.12 as it crosses along the old narrow gage embankment and terminates near the guardrail at Rt. 1A. The total length of the wall is 500 feet. Temporary sandbag closures would be provided at each end of the wall. A closure is included across Revere Beach Boulevard between the ponding area wall and the Revere Beach seawall. At the opposite end of the wall a closure is provided across Rt. 1A, if needed, to direct water across Rt. 1A to the estuary. The third closure may be needed across the north end of the Boulevard at the Carey Circle Wall.

7. MITIGATION - CLAM FLAT AREA

A clam flat basin would be constructed and developed along the north side of the I-95 embankment about 1000 feet east of Copeland Circle and immediately south of the Seaplane Basin. The I-95 embankment will be cut to El.9 feet NGVD by others prior to plan mitigation. The Revere Beach Erosion Control Project would remove part of it and some has currently been removed. The location could be shifted to the east to be totally located over fill removed by the Revere Beach project, if necessary.

The I-95 embankment would be cut out for a 13 acre basin (including 10 acres for clam flats) between El. 9 and -4 ft NGVD. A ten foot wide buffer zone would remain around the top perimeter (2200 feet long) of the basin and cover 0.5 acres. The basin's tides would flush through an opening excavation into the Seaplane Basin. Outside of the buffer zone a permanent berm is required to El. 11.0 ft NGVD to protect the basin from being breached by storm water levels approaching El. 8 ft NGVD. The berm would have a 10 foot top width and 3 on 1 side slopes and would be used for access to the site after construction.

The total 14 acre site would have 10 acres transplanted with clams from the Seaplane Basin flats and a 2.5 acre fringe of marsh grass transplanted from the nearby marsh. The 0.5 acre buffer zone and 1 acre berm would be protected with grass. The buffer zone would help protect further the integrity of the basin by reducing erosion of the basin's sloping surface. In design the buffer zone would be further considered for shrubs, boulders or fences to protect erosion of the area from recreation vehicles.

Approximately 186,000 cubic yards (cy) of granular materials and 4,000 cy of organic materials will be excavated for the basin. The granular materials and peat will be excavated with a backhoe or dragline and transported by truck to appropriate areas. It appears that 76,000 cy of the granular materials excavated (El. 9 feet to El. 5 feet) should be relatively clean. The clean granular materials will be used for the Revere Park dike's random fill section (56,000 cy) or sold for general use from a stockpile located east of the basin. The remaining 20,000 cy would be temporarily stockpiled near the site for use by others. It is assumed that the remaining 110,000 cy of granular materials excavated (El. 5 feet to El. -4 feet) would have a high salt content because it is presently situated in the tidal zone. It would be used for the: protective berm around the site (3,000 cy); and dumped granular fill and random fill sections of the Lynn dikes and walls (72,000 cy). The remaining high salt content material (about 35,000 cy) could be used for various purposes including beach maintenance and road sanding. It would be stored adjacent to the protective berm around the basin. The organic materials will be trucked off site to a disposal area.

8. ESTUARY STORAGE AREA

The Saugus and Pines River estuary would be used for flood water storage of interior runoff and tidal overtopping of the shorefront. The design storage volume needed for storage is 5400 acre-feet for a combined SPN tide event coincident with a 100 year runoff form the water-shed. For this design event, the required storage is available between elevations 2 and 8 feet NGVD. The area needed for storage is estimated to range from 1500 to 1600 acres. During design, detailed mapping and delineations of the storage area would refine the acreage and location of the storage area. Plates D1 and D12 to 22 show the estimated locations and boundary limits of the Estuary Storage Area.

9. MAINTAIN EXISTING REVERE BEACH

The beach and seawall at Revere Beach must be maintained so as not to be allowed to erode or deteriorate below existing conditions thus allowing increased overtopping and flooding. The existing seawalls are about 14,540 feet long bordering the beach which is about 13,000 feet long. Plates D17 to D31 show profiles of the existing beach and seawall.

Construction of the authorized Revere Beach Erosion Control Project would meet this project requirement. With the Erosion Control Project, the sand along the seawalls would be built up to Elevation 13.4 feet NGVD for a distance of 50 feet from the seawall before sloping off at a 1 foot drop every 15 feet to meet the existing beach.

The communities should also maintain the existing ponding areas and tide gates which reduce flooding, many of which are shown on Plates D12 to D22.

D. OTHER PLANS INVESTIGATED

Other alternative plans for flood damage reduction have been investigated. A description of these plans is contained in the Plan Formulation Appendix which includes Local Protection Plans (shown on Plate D32), Non-Structural Plans and various floodgate alignments and locations.

E. CONSTRUCTION PROCEDURE, SEQUENCE AND SCHEDULE

Construction of the floodgate structure will take approximately 3.5 years to complete. This schedule is based on 8 hour working days, 5 days per week, 52 weeks per year, excluding holidays.

Access to the site and staging area for the main concrete structure will be from the MDC property on the Lynn side. It is here that the contractor will store materials, park equipment, possibly locate a concrete batch plant, locate contractor and government office trailers, etc. Access for the earth dike and related concrete walls will be from Rice Avenue.

The major dredging effort will be performed during the months of December, January and February. Two clam shell dredges mounted on deck scows will be required during this time period. Dredge material will be loaded on dump scows and towed to the disposal site in Massachusetts Bay. Additional small amounts of dredging will be required later in the construction. Any dredging required for the gates, outside the November to February window, should be done inside the cofferdams to avoid impacts on fisheries.

Construction of both the ring wall and braced cofferdams will be done from a barge. Also, from a barge, bearing piles will be augured and driven inside the dog-eared braced cofferdams for the tainter gates. Bearing piles for the navigation gate will be driven from inside the ring wall cofferdam.

Construction materials (concrete, gravel, stone fill, etc.) will be transported and placed by barge. Concrete, however could be pumped from the landside to the project work. Construction materials for the earth dike will probably be furnished directly to the site using 16 cubic yard dump trucks because of the limited work area seaward of Rice Avenue. If design determines that the reuse of dredged material for back filling gate abutments continues to be feasible, additional environmental documentation may be required.

No excavation was assumed for the first phase of the Revere dike. This may change once a subsurface investigation is complete. The earth and stone fill for the dike would be dumped from trucks, spread with dozer type equipment and compacted if applicable. The second phase of the Revere dike will be constructed in a similar manner, however it will not be done during the most favorable time of year for this type of work. Cold temperatures, frost and possibly snow make it impossible to perform earth work. The time allotted for completion of this phase may be optimistic. Further investigation should be conducted to examine the necessary time for settlement. If settlement time were reduced it would place this work in a better time frame making for a more realistic construction duration.

Construction of the remaining features of the regional plan will start approximately 1 year before the floodgate structure. These features (i.e. Lynn Harbor dikes and walls, Point of Pines, Revere Park dike, Ponding area wall and the clam flat mitigation) will take at least 1 year to complete. This is an approximate duration and may be revised upon further review of the different individual features.

The following is the proposed sequence of construction. The estimated time required for design and construction are shown on Figure 4A and 4B. The Park Dike, Ponding Area gravity wall, Lynn Harbor Dikes and walls and Point of Pines revetments, dunes, beach and wall would be constructed under the first contract following 4 years of design, preparation of plans and specifications and contract award.

The floodgate structure would be constructed under a second contract starting near the completion of the other features. Construction would take about 3.5 years to complete. It would be constructed in phases shown on Figures 1, 2, and 3. The phasing would maintain a minimum flow area below El. 0.0 ft NGVD of 5200 sf to maintain safe flows for navigation and the natural flushing of the estuary.

PHASE	DESCRIPTION
1.	(Figure 1)
1A	Dredge temporary navigation channel and river bottom to finish grade at El. -14.0 and dredge for cofferdams (See Plates D2, 2A, 3 and 4). Install ring cofferdam, then bearing piles (BPs) and build navigation gate. Following 3 months for mobilization and dredging, the gate would take about 16 months to complete.
1B	Concurrently, install braced cofferdam (BCD) then BPs for first 4 tainter gates and gravity wall on Lynn side and construct, then remove BCD. The flow area at mid tide is about 5,500 sf until BCD's are removed.
2.	(Figure 2)
2A	With the navigation gate open, dredge for remaining BCD's and install BCD for Revere gate and construct, about 5 months.
2B	With the Lynn gates #1 -#4 open, install BCD then BP's and construct remaining five tainter gates on Lynn side, over about a 15 month period. During phase 2A and 2B about 5,700 sf of flow area is available.
3.	(Figure 3)
3A	After completion of the Revere tainter gate (2A) open it and proceed with the BCD then BPs and construct the Revere gravity wall and I-Wall followed by the Revere dike to El. 10.0 ft NGVD, about a 7 month period. During this period, which overlaps phase 2B, at least 5,300 sf of flow area is available.
3B	During construction of the Revere Dike construct the PZ-27 steel sheet pile walls in Reach D Lynn Harbor using reused SSP from the BCD's. After about a 6 month consolidation period, complete the Revere dike above El. 10.0 ft NGVD over about a 1 month period. Following completion of the Revere and Lynn gates, all gates are open with the total 8,800 sf of flow area available at peak flow or mid tide (El. 0.0 ft NGVD).

F. CONSTRUCTION MATERIALS

A description of the characteristics of the materials to be used in the construction of the embankments and revetments is contained in the Geotechnical Appendix. Other construction materials include steel sheet piles for Cofferdams and walls, prestressed concrete bearing piles, steel miter gates and tainter gates, concrete and reinforcement steel. The concrete, reinforcing steel, stone and other bulk fill materials is available from commercial suppliers within a 50 mile radius of the study area. The other items noted would need to be ordered from manufacturers located outside the region. Prestressed concrete piles are available from "San Vel Concrete" in Ayer, Massachusetts.

G. CONSTRUCTION FACILITIES

1. Contractor Facilities

The construction of the project will require a considerable work force comprised of varied construction skills, but concentrated mostly in the heavy equipment and semiskilled trades. Within the greater Boston area there is a sufficient number of workers who would commute to work and not require housing near the project site. There would be a need for administration, mobilization and storage of equipment and materials at the project site. A few locations have been investigated for such use. These are; West of Ocean Avenue between Beach Street and Revere Street, in Revere and the southern end of the Lynn Harbor area on the New England Telephone Company property. All temporary facilities required by the contractor would be removed at the conclusion of work and the site restored as required.

2. Government Facilities

A field office would be required in the vicinity of the project. A winterized office trailer would be furnished as an ancillary obligation under the construction cost.

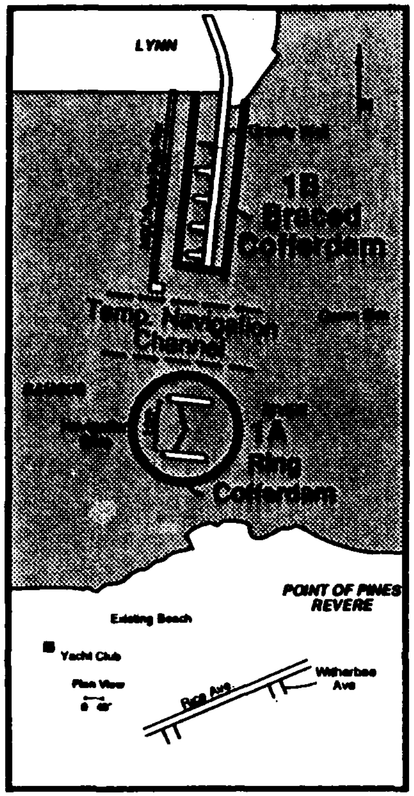


FIGURE 1

PHASE 1 CONSTRUCTION

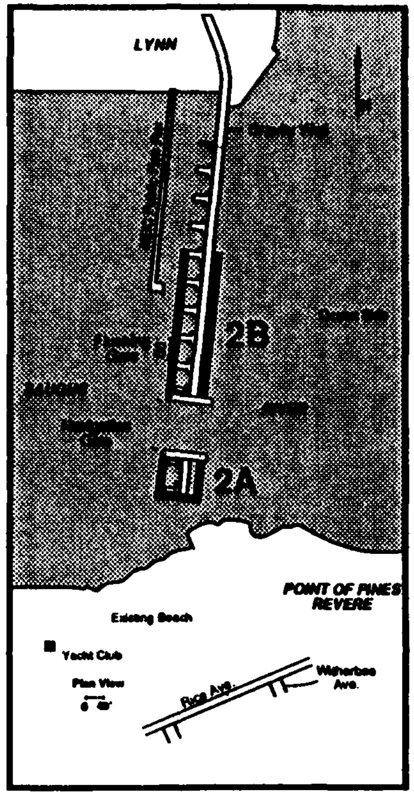


FIGURE 2

PHASE 2 CONSTRUCTION

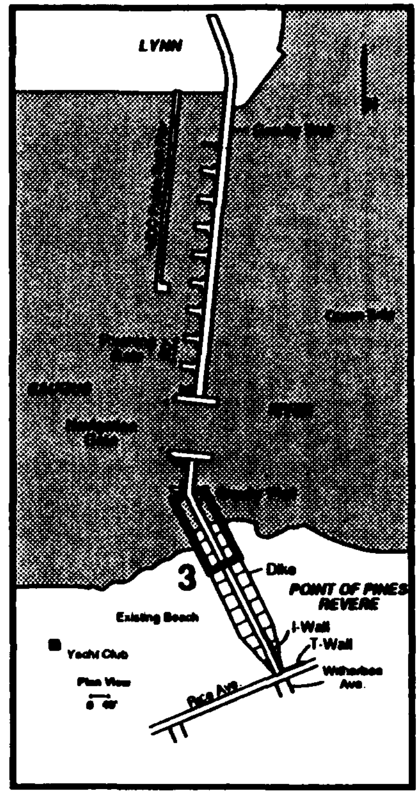


FIGURE 3

PHASE 3 CONSTRUCTION

Figures 1, 2 and 3

APPENDIX D

PROJECT COST ESTIMATE

PROJECT COST ESTIMATE

General Narrative:

Project costs estimates are included for the selected plan - identified as the SPN (Standard Project Northeaster) plan with a design stillwater tide level of elevation 12 ft. NGVD and two other plans which are designed for the 500 year and 100 year flood levels with design stillwater tide levels of elevation 11.2 and 10.3 ft. NGVD, respectively. The design level applies to the Floodgate structure, structure along Lynn Harbor, Revere Beach Dikes and the Point of Pines wall along the Saugus River. Only the remaining Point of Pines shorefront feature are designed for the 100 year level in all three plans. These estimates are organized by major construction feature and subfeature using cost account designations. Also for the selected plan a separate major feature summary is provided.

Unit prices have been derived from recent historical data, actual quotes from suppliers, cost reference manuals and knowledge and experience. Where appropriate, prices were escalated for time differences and adjusted for location and site specific factors.

Contingencies are shown for each line item. Individual contingencies were determined from group discussions with the design team and reflect the general level of design effort and confidence in the given material, quantities and method of construction. Contingency values are carried forward to subfeatures and features using the 'contingency amount'.

The Plan Formulation Appendix compares costs developed for other alternatives, including Miter vs. Sector gates, Tainter vs. Sluice gates, Cellular vs. Braced Cofferdams, alternate floodgates alignments, local protection and nonstructural plans.

FLOODGATES: Several different gate designs were considered for both the navigation gate and the flushing gates. These gates were evaluated for lowest first mechanical cost. The costs presented were based on actual quotes from Rodney Hunt Co. of Orange, Massachusetts or derived from previous projects. Costs derived from previous projects were increased or decreased on a square foot basis to correspond to the size gate required for the Saugus River Project, and then escalated to September 1988 costs using ENR escalation rates.

Navigation Gates: The two different types of gates evaluated for the navigation opening were sector gates and miter gates. The initial cost comparison of these two gates are shown in the Plan Formulation Appendix. The miter gate was selected since it would cost $10 million less than the Sector Gate.

Cost for the miter gate is based on Olmstead Lock and Dam gate cost data supplied by the Louisville District. Costs supplied were escalated to September 1988 using ENR escalation rates. The costs were also escalated from the lower Illinois area to the Metropolitan Boston area for material and labor.

The base price of the miter gate for the selected, SPN, plan was calculated to be $2,805,000 which was increased 20% to provide for installation from a barge and 2% to provide for cleaning and painting. To this price was added overhead and profit markups of 20.5% which resulted in a total estimated cost of $4,124,000. A contingency amount of 40% was applied to this feature due to potential design changes to provide added strength to withstand wave action and potential size or type of gates changes which may be indicated by model studies of the estuary to be performed by the Corps' Waterways Experiment Station (WES) in Vicksburg, Mississippi.

Flushing Gates: Several alternatives were also considered for the flushing openings. These alternatives included sluice gates, flap gates, roller gates, drum gates and tainter gates. The table below shows the mechanical installed cost of four different gates. The drum and roller gates were discarded early in the study because of higher costs. The gate costs shown were subsequently updated to 1988 price levels. The tainter gates show the lowest installed cost. The Plan Formulation Appendix also compares the tainter gate and sluice gate costs for the gate, concrete, and bearing piles. Ten tainter gates would cost about $10 million less than the construction cost of sluice gates. The tainter gate was therefore selected. Gate sizes, types, numbers required and installed costs are presented in the following table from which the system of ten 15'x50' tainter gates were chosen. Model studies will further define any changes needed in the gates, such as raising the top elevation, reducing the number of gates required or other dimensional changes.

FLUSHING GATES

Gate Type	Size	No. of Gates	Mechanical Cost for Gate Installed ($000)
Sluice	10'x10'	70	$ 7,198
Flap	"	"	6,018
Flap	12'x12'	49	6,507
Tainter	15'x50'	10	4,525

All costs for the flushing gates were obtained from Rodney Hunt Co. of Orange, Massachusetts, a local gate manufacturer who has manufactured gates of similar sizes. The base price listed above was increased by 20% to provide for installation from a barge and to this was added overhead and profit markups of 20.5%. The resulting price for the ten (10) tainter gates was $6,543,000. A contingency amount of 20% was applied to this feature to allow for design changes which may be indicated by model studies by WES.

Dredging: Dredging is assumed to be performed mechanically using a clam shell dredge mounted on a deck scow, loading a dump scow and towing to the disposal site in Massachusetts Bay. This effort is reflected in the unit cost. Further testing of the sediment may show it to be suitable for use on Point of Pines beach which would significantly reduce costs for this effort. Most dredging will occur at the start of construction for the floodgate structure. Additional dredging would follow prior to installing cofferdams.

The very large contingency of 75% was used to allow for additional quantities of dredging which may be required for plant mobility and an additional channel which may be necessary to alleviate scour near the mitre gate.

Cofferdams: Braced and cellular cofferdams were evaluated. The braced cofferdam, using a ring around the miter gate and walls around the tainter gates were found to be about $20 million less expensive than the filled cellular type. Although the cellular type would ease construction work, the braced cofferdam requires less room to construct, affecting less of the river bottom and flow area.

New cofferdam material including steel sheet piles (SSP)and bracing would be purchased for the initial phase of construction and reused for subsequent phases of cofferdam construction. This has been noted in the estimate where prices reflect labor and equipment only. The SSP PZ 27 used in the cofferdams would be used last for the Lynn Harbor Reach D Wall.

A contingency of 20% was considered appropriate to provide for changes during final design due in part to lack of subsurface information.

Dewatering: This item was estimated assuming that 6-inch centrifugal pumps (est. 2.1 MGD) would be in use continuously during all phases of work within the cofferdams. No analysis of inflow was performed. It was assumed that 2 pumps each should be adequate for construction involving the miter gate and tainter gates 1-4, 1 pump for tainter gate 10, 3 pump for tainter gates 5-9 and 1 pump for the gravity wall. One spare pump would be available at all times and maintenance would be performed using two crews operating continuously in 12-hour shifts.

A higher contingency of 30% was assigned since no analysis has been performed and additional pumps may be required. In addition, handling the pumps will be difficult within the cofferdams.

Prestressed Concrete Piles: Piles were sized at 12"x12" without detailed design analysis or subsurface exploration data. All piles were assumed to be 90 feet in length. Costs were quoted from R.A. Francoeur, Inc of Salisbury, Massachusetts, and indicate that piles driven from a barge would cost twice the amount for land driven piles.

Piles under the navigation gates would be augered and driven from a gravel working mat after the cofferdam is built and dewatered. All other piles would be augered and driven from a barge.

A higher contingency of 30% was assigned to this item due to the very limited foundation data. In addition, the contingency accounts for the fact that the Office of the Chief of Engineers is in the process of updating Civil Works Design Criteria. More stringent seismic criteria for structure is anticipated.

Concrete: Analysis of concrete has not been performed to date and, therefore, section designs and reinforcement (where indicated) are subject to changes. Cost presented for plain and reinforced concrete were derived from historic data and adjusted to FY88 prices. The cost presented includes concrete formwork, installation, steel, joints, finish and curing. The basic prices for reinforced and plain concrete, $350/CY and $250/CY respectively, were adjusted further considering the specific characteristics of each feature of work. Prices were increased 25% to allow for the more difficult working conditions within the braced cofferdams. Unit prices for thin wall structures were increased due to the additional formwork required.

A 100% contingency was assigned to the reinforced concrete item for the "I" wall used as a closure between the dike and "T" wall on the Revere side of the tidal barrier. Preliminary civil layout indicates that the height of fill to be retained by this wall is the maximum for which an "I" wall would be structurally adequate. Further design development may dictate that a more costly alternative type wall be used for the closure.

Construction Fill Materials: Cost for construction fill materials were derived from historic data and include material, placement, compaction (if required) and all markups. In addition, quotes were solicited from area vendors which, when considering the rehandling required to bring the material to the site, tend to agree with the stated prices.

Average to low contingencies of 15% - 20% were assigned to these items which reflect the general confidence in the quantities provided. However, the stone blanket and gravel bedding items under the Navigation gate feature were assigned contingencies of 200% and 100% respectively to allow for potential scour problems which may require additional dredging and erosion protection measures.

Wick Drains: Wick drains are required along the dike portion of the flood gate structure to expedite consolidation of the compressible subsurface materials. Since detail analysis of requirements has not been performed, a higher contingency was assigned to provide for additional drains.

MDC Fish Pier Removal (if necessary): The existing fish pier is located just upstream of the proposed Saugus River Floodgate structure on the Lynn side. It is a pile and timber structure with an estimated total area of 5,800 SF. The cost estimate is based on a previously bid project involving the demolition and removal of a pier of similar construction and size. The cost was determined using the unit price per square foot and adjusted using the Corps of Engineers Civil Works Construction Cost Index System composite cost index. The cost includes demolition, removal and disposal. The price is considered reasonable and a contingency of 20% is added to provide for potential increases due to the actual location of the disposal site and disposal fees. Design, modelling and future layouts will determine if the pier must be removed, that is, if it interferes with tidal flows or cofferdams. If removed, it is expected the non Federal Sponsor would elect to use the Floodgate walls for public fishing, in lieu of rebuilding the pier at non Federal expense.

Restoring Rice Avenue and the Revere Park Dike: This effort includes removing an existing wall (~ 250 LF), providing turf, shrubs and trees to replace those to be removed during construction. Cost for trees assume a generic tree 8 to 10 feet tall.

Mitigation: The mitigation site includes the excavation of 190,000 cy of material, seeding of grass and transplanting of marsh grass and clams. A 20% contingency is included in the event a retransplant is required as well as a study to determine why problems were encountered on the first attempt. Some variation in quantities and excavation costs, depending on actual site conditions, would also be covered by the contingency.

Engineering and Design Costs (E&D): A separate estimate is attached for Engineering and Design costs at about $7,230,000.

Engineering During Construction (EDC): EDC costs are estimated at 0.5% of the project direct costs or $320,000.

Supervision and Inspection (S&I): S&I costs during construction are estimated at $3,680,000, or about 6% of the project cost.

Engineering & Design and Supervision & Administration Costs (E&D, S&A): The following summarizes the projects estimated E&D and S&A costs:

	TOTAL	E&D	S&A
PE&D Labor	$ 4,130	$ 3,350	$ 780
PE&D Contract & Models	3,100	3,100	-
EDC	320	270	50
S&I	3,680	-	3,680
TOTAL E&D, S&A	$11,230	$ 6,720	$4,510

Real Estate: Real estate costs are summarized in the main report and developed in the Real Estate Appendix at a cost of $3,644,000.

SENSITIVITY OF COST ESTIMATES: The following presents a sensitivity analysis of major features, quantities, and unit costs in the estimate.

Floodgate Structure - Major items which are cost sensitive and affect changes in the cost estimate are:

(1) The navigation gate structure ($14,092,000) has a unit cost of about $140,920 per linear foot of opening for (100 ft) gate, $7,800 per sf of opening (1800 sf) below mid tide (El. 0.0) or $427,000 per ft. of height (33 ft).

(2) The flushing tainter gate structures (about $2,987,900 each) have unit costs of $60,000 per linear foot of gate opening (50 ft), or $4,270 per sf of opening (700 sf) below mid tide (El. 0.0).

(3) The Revere gravity wall (140 lf) cost per lf is $13,450 compared to the cost per lf $4,470 of the dike (165 lf). The dike is also sensitive to the slope. If the 1:3 slope should be reduced to 1:2, it would not only reduce the cost of embankment, but also the length of the Revere gravity wall (140 lf) tie in. (The average height of the gravity wall is higher than the average dike height.)

(4) Adding or deleting one tainter gate changes the direct cost by about 3 million.

Project Expenditures

The following are the estimate project expenditures and real estate values by fiscal year at October 1988 price levels in $1000:

	PED	Other Than Floodgate Construction	Real Estate	Total
F90	$2,826			$ 2,826
F91	1,868			1,868
F92	1,226			1,226
F93	890			890
F94	420	$18,300	$ 3,150	$21,870
		Floodgate Construction	Floodgate Real Estate	
F95	-	$15,930	$ 494	$16,424
F96	-	16,570	-	16,570
F97	-	15,500	-	15,500
(1st Q) F98	-	1,768	-	1,768
Total	7,230	$68,068	$3,644	$78,942

Federal and Non Federal Costs (in $1,000) by Fiscal Year:

	Federal		Non Federal	
F90	$ 2,826		-	
F91	1,868		-	
F92	1,226		-	
F93	890		-	
F94	11,832		$ 6,888 and	
	-		3,150 (real estate)	
F95	10,676		5,254 and	
	-		494 (real estate)	
F96	10,770		5,800	
F97	10,075		5,425	
F98 (1st Q)	1,149		619	
Total	$51,312	(65%)	$27,630	(35%)

Project Total $78,942

Note: PE&D or PED refers to Preconstruction Engineering and Design.

STANDARD PROJECT
NORTHEASTER
(SPN)

COST ESTIMATE

SAUGUS RIVER AND TRIBUTARIES - CWIS NO. 14021
REGIONAL SAUGUS RIVER FLOODGATE PLAN - ALIGNMENT NO. 2
(October 1988 Price Levels)

STANDARD PROJECT NORTHEASTER (SPN)

SUMMARY OF COSTS BY COST ACCOUNT

COST ACCOUNT NUMBER	COST ACCOUNT	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
01.	LANDS AND DAMAGES	$2,915,000	25.0%	729,000	$3,644,000
02.	RELOCATIONS	510,000	20.6%	104,732	695,000
05.	LOCKS	10,642,000	32.4%	3,450,000	14,092,000
06.	FISH AND WILDLIFE FACILITIES	324,000	20.8%	67,300	391,000
11.	LEVEES AND FLOODWALLS	39,654,000	22.0%	8,742,000	48,396,000
17.	BEACH REPLENISHMENT	164,000	23.1%	38,000	202,000
19.	BUILDINGS, GROUNDS AND UTILITIES	243,000	20.0%	49,000	292,000
30	ENGINEERING AND DESIGN	5,600,000	20.0%	1,120,000	6,720,000
31.	SUPERVISION AND ADMINISTRATION	3,608,000	25.0%	902,000	4,510,000
	TOTAL PROJECT FIRST COST	$63,660,000	23.9%	$15,202,032	$78,942,000

NOTE: Estimates for Cost Accounts 01, 30 and 31 are developed elsewhere in this report.

SAUGUS RIVER AND TRIBUTARIES - CWIS NO. 14021
REGIONAL SAUGUS RIVER FLOODGATE PLAN - ALIGNMENT NO. 2
(October 1988 Price Levels)

STANDARD PROJECT NORTHEASTER (SPN)

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
01.	LANDS AND DAMAGES							
	aquisitions and easements				$2,915,000	25.0%	$729,000	$3,644,000
	TOTAL COST ACCOUNT 01. LANDS AND DAMAGES				$2,915,000	25.0%	$729,000	$3,644,000
02.	RELOCATIONS							
	Drainage System for Reach B and C							
	12" RCP	400	LF	20.00	8,000	25.0%	2,000	10,000
	18" RCP	575	LF	25.00	14,375	25.0%	3,594	17,969
	24" RCP	65	LF	30.00	1,950	25.0%	488	2,438
	36" RCP	15	LF	60.00	900	25.0%	225	1,125
	plug 12" pipe	5	EA	500.00	2,500	25.0%	625	3,125
	tie pipes to exist MH	9	EA	500.00	4,500	25.0%	1,125	5,625
	remove exist pipe	100	LF	10.00	1,000	25.0%	250	1,250
	manhole	1	EA	2,000.00	2,000	25.0%	500	2,500
	sluice gate (18"x18")	1	EA	4,400.00	4,400	25.0%	1,100	5,500
	sluice gate (36"x36")	1	EA	13,200.00	13,200	25.0%	3,300	16,500
	sluice gate & closure for 60" pipe	1	LS	38,500.00	38,500	20.0%	7,700	46,200
	Subtotal Drainage System				$91,325	22.9%	$20,906	$112,000
	sluice gate & closure for 60" pipe	1	LS	38,500.00	38,500	20.0%	7,700	46,200
	Lynn Reach F							
	sluice gate (72"x72")	1	EA	24,200.00	24,200	20.0%	4,840	29,040
	sluice gate (84"x84")	1	EA	31,900.00	31,900	20.0%	6,380	38,280
	sluice gate (48"x48")	1	EA	16,500.00	16,500	20.0%	3,300	19,800
	Park Dike South							
	replace conc sidewalk (6")	2,187	SY	60.00	131,220	20.0%	26,244	157,464
	Park Dike North							
	replace conc sidewalk (6")	1,576	SY	60.00	94,560	20.0%	18,912	113,472
	Sales Cr sluice gate (72"x72")	1	EA	24,200.00	24,200	20.0%	4,840	29,040
	Revere Park Dike N/S Floodwalls							
	replace 3" bit conc. pavement	220	SY	16.00	3,520	25.0%	880	4,400
	remove mdc fish pier(if req'd)	5,800	SF	$9.25	$53,650	20.0%	$10,730	$64,380
	TOTAL COST ACCOUNT 02. RELOCATIONS				$509,575	20.6%	$104,732	$695,000

SAUGUS RIVER

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
05. LOCKS								
	mitre gate	1	EA	$4,124,000.00	$4,124,000	40.0%	$1,650,000	$5,774,000
	piles - auger	12,700	LF	3.00	38,100	30.0%	11,000	49,100
	piles (12 sq. in. prestressed)	12,900	LF	30.00	387,000	30.0%	116,000	503,000
	reinforced concrete	5,890	CY	350.00	2,061,500	20.0%	412,000	2,473,500
	stone blanket	670	CY	40.00	26,800	200.0%	54,000	80,800
	gravel bedding	710	CY	16.00	11,360	100.0%	11,000	22,360
	dredge for cofferdam(-27.5ngvd	23,100	CY	7.80	180,180	75.0%	135,000	315,180
	dredge site (-14) & channel	55,600	CY	7.80	433,680	75.0%	325,000	758,680
	backfill gates & channel	19,100	CY	8.00	152,800	10.0%	15,000	167,800
	cofferdam							
	SSP - PZ-27 (new material)	1,158,300	LB	0.70	810,810	20.0%	162,000	972,810
	piles (pull & stockpile)	1,158,300	LB	0.30	347,490	20.0%	69,000	416,490
	12 in. dia. pipe spud	209,000	LB	0.70	146,300	20.0%	29,000	175,300
	pipe spud (pull & stockpile)	120,000	LB	0.30	36,000	20.0%	7,000	43,000
	box girders	775,000	LB	1.00	775,000	20.0%	155,000	930,000
	gravel	1,300	CY	15.00	19,500	10.0%	2,000	21,500
	site preparation	1	LS	25,000.00	25,000	20.0%	5,000	30,000
	operator - house no. 1	1	LS	165,000.00	165,000	20.0%	33,000	198,000
	operator - house no. 2	1	LS	75,000.00	75,000	20.0%	15,000	90,000
	generator (installed)	1	LS	100,000.00	100,000	20.0%	20,000	120,000
	utilities	1	LS	50,000.00	50,000	20.0%	10,000	60,000
	railing	300	LF	15.00	4,500	20.0%	1,000	5,500
	dewatering	1	LS	504,700.00	504,700	30.0%	151,000	655,700
	dolphins - 4	1	EA	117,430.00	117,430	40.0%	47,000	164,430
	aids to navigation	1	LS	50,000.00	50,000	30.0%	15,000	65,000
	TOTAL COST ACCOUNT 05. LOCKS				$10,642,150	32.4%	$3,450,000	$14,092,000
06. FISH AND WILDLIFE FACILITIES - MITIGATION								
	excavate clean sand							
	used on Park Dike	56,000	CY		see Park Dike estimate			
	stockpiled on site	20,000	CY	$4.00	$80,000	20.0%	16,000	$96,000
	excavate salty sand						0	
	used to build berm	3,000	CY	4	12,000	20.0%	2,000	14,000
	used in Lynn Hbr Dikes/ POP	72,000	CY		see Lynn Harbor estimate			
	stockpiled on site	35,000	CY	4.00	140,000	20.0%	28,000	168,000
	excavate peat	4,000	CY	5.50	22,000	20.0%	4,000	26,000
	seed berm	110	MSF	48.00	5,280	25.0%	1,000	6,280
	plant marsh grass (0.5 acre)	1	AC	2,300.00	1,150	25.0%	300	1,450
	fertilizer (0.5 acre)	1	AC	1,200.00	600	25.0%	0	600
	transplant clams	10	AC	6,290.00	62,900	25.0%	16,000	78,900
	TOTAL COST ACCOUNT 06. FISH AND WILDLIFE FACILITIES				$323,930	20.8%	$67,300	$391,000

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
11.	LEVEES AND FLOODWALLS							
	Flushing Gates							
	tainter gates (15'x 50')	10	EA	$654,300.00	$6,543,000	20.0%	1,309,000	$7,852,000
	reinforced conc. + 25 % labor	7,570	CY	437.50	3,311,875	20.0%	662,000	3,973,875
	concrete + 25 % labor	6,785	CY	312.50	2,120,313	20.0%	424,000	2,544,313
	piles (12' sq. prestressed)	71,012	LF	60.00	4,260,720	30.0%	1,278,000	5,538,720
	stop log	1	LS	547,000.00	547,000	20.0%	109,000	656,000
	site preparation	1	LS	40,000.00	40,000	20.0%	8,000	48,000
	braced cofferdam							
	PZ-27 (new materials)	1,498,000	LB	0.70	1,048,600	20.0%	210,000	1,258,600
	PZ-27 (pull & stockpile)	1,498,000	LB	0.30	449,400	20.0%	90,000	539,400
	PZ-27 (drive and pull)	1,334,250	LB	0.45	600,413	20.0%	120,000	720,413
	HP 12x63 (new materials)	180,000	LB	0.80	144,000	20.0%	29,000	173,000
	HP 12x63 (pull & stockpile)	180,000	LB	0.60	108,000	20.0%	22,000	130,000
	HP 12x63 (drive and pull)	118,000	LB	0.60	70,800	20.0%	14,000	84,800
	struts & whalers(materials)	2,188,000	LB	0.50	1,094,000	15.0%	164,000	1,258,000
	struts & whalers (labor)	2,077,000	LB	0.30	623,100	15.0%	93,000	716,100
	struts & whalers (reused)	2,188,000	LB	0.30	656,400	15.0%	98,000	754,400
	gravel (gates & wall)	4,120	CY	15.00	61,800	10.0%	6,000	67,800
	gravity wall - Lynn							
	reinforced conc. + 25% labor	387	CY	437.50	169,313	20.0%	34,000	203,313
	concrete + 25 % labor	1,615	CY	312.50	504,688	20.0%	101,000	605,688
	piles (12 sq. in. prestress)	4,960	LF	60.00	297,600	30.0%	89,000	386,600
	dredging	27,800	CY	7.80	216,840	75.0%	163,000	379,840
	dredge & place at gates	7,700	CY	4.00	30,800	75.0%	23,000	53,800
	stone blanket at gates	2,930	CY	40.00	117,200	10.0%	12,000	129,200
	gravel bedding at gates	2,930	CY	16.00	46,880	10.0%	5,000	51,880
	handrail	1,440	LF	15.00	21,600	20.0%	4,000	25,600
	guard rail	1,440	LF	15.00	21,600	20.0%	4,000	25,600
	dewatering	1	LS	1,309,000.00	1,309,000	30.0%	393,000	1,702,000
	Subtotal Flushing Gates				$24,414,940	22.4%	$5,464,000	$29,879,000
11.	Gravity Wall, Revere, 140 LF							
	concrete + 25 % labor	1,300	CY	$312.50	$406,250	20.0%	81,250	$487,500
	reinforced conc. + 25 % labor	380	CY	437.50	166,250	20.0%	33,250	$199,500
	excavation	490	CY	8.00	3,920	20.0%	784	$4,704
	piles (12 sq. in. prestressed)	4,900	LF	60.00	294,000	30.0%	88,200	$382,200
	site preparation	1	LS	10,000.00	10,000	20.0%	2,000	$12,000
	braced cofferdam (prices for labor only - materials re-used form other phases)							
	struts	437,230	LB	0.60	262,338	15.0%	39,351	$301,689
	lateral struts	123,840	LB	0.60	74,304	15.0%	11,146	$85,450
	wales	66,720	LB	0.60	40,032	15.0%	6,005	$46,037
	HP 12 x 63 (drive & pull)	97,020	LB	0.60	58,212	20.0%	11,642	$69,854
	piles (PZ-27 drive & pull)	438,480	LB	0.45	197,316	20.0%	39,463	$236,779
	guard rail	300	LF	15.00	4,500	15.0%	675	$5,175
	dewatering	1	LS	40,350.00	40,350	30.0%	12,105	$52,455
	Subtotal Gravity Wall, Revere				1,557,472	20.9%	$325,871	$1,883,000

SAUGUS RIVER

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
11.	Dike Phases I & II, 165 LF							
	stone protection	2,222	CY	$45.00	$99,990	15.0%	14,999	$114,989
	gravel bedding	5,413	CY	16.00	86,608	15.0%	12,991	99,599
	silty sand core	8,876	CY	10.00	88,760	15.0%	13,314	102,074
	dumped rock toe	2,149	CY	35.00	75,215	20.0%	15,043	90,258
	geo-membrane (Hypalon)	19,867	SF	0.75	14,900	20.0%	2,980	17,880
	site preparation	1	LS	10,000.00	10,000	20.0%	2,000	12,000
	guard rail	453	LF	15.00	6,795	20.0%	1,359	8,154
	wick drains	225	EA	1,000.00	225,000	30.0%	67,500	292,500
	Subtotal Dike				607,268	21.4%	130,186	$737,000
11.	I-wall and Access Ramp							
	reinforced conc. + 25% labor	88	CY	$437.50	$38,500	100.0%	38,500	$77,000
	dredge	128	CY	8.00	1,024	75.0%	768	1,792
	compacted random fill	96	CY	8.00	768	10.0%	77	845
	steel sheet pile PZ27	93,960	LB	0.70	65,772	20.0%	13,154	78,926
	site preparation	1	LS	2,000.00	2,000	20.0%	400	2,400
	stone protection	330	CY	45.00	14,850	10.0%	1,485	16,335
	gravel	810	CY	16.00	12,960	10.0%	1,296	14,256
	silty sand core	490	CY	10.00	4,900	10.0%	490	5,390
	access gate	1	LS	1,500.00	1,500	20.0%	300	1,800
	guard rail	160	LF	15.00	2,400	20.0%	480	2,880
	Subtotal I-wall and Access Ramp				$144,674	39.4%	$57,000	$202,000
11.	Lynn Harbor Dikes and Walls Reach B							
	excavation (dike)	11,700	CY	$8.00	$93,600	30.0%	$28,000	$121,600
	dumped granular	24,840	CY	10.00	248,400	30.0%	75,000	323,400
	compacted random fill	1,620	CY	8.00	12,960	30.0%	4,000	16,960
	compacted imperv	10,638	CY	12.00	127,656	20.0%	26,000	153,656
	gravel bedding	5,274	CY	16.00	84,384	15.0%	13,000	97,384
	stone protection	13,356	CY	45.00	601,020	15.0%	90,000	691,020
	topsoil seeded	2,394	SY	4.50	10,773	75.0%	8,000	18,773
	remove exist bulkhead	1,800	LF	10.00	18,000	75.0%	14,000	32,000
	stone bedding	5,472	CY	30.00	164,160	15.0%	25,000	189,160
	Subtotal Reach B				$1,360,953	20.8%	$283,000	$1,644,000

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
11.	Reach C							
	excavation (dike)	7,350	CY	$8.00	$58,800	30.0%	$17,640	$76,440
	dumped granular	17,250	CY	10.00	172,500	20.0%	34,500	207,000
	compacted random fill	1,350	CY	8.00	10,800	15.0%	1,620	12,420
	compacted impervious fill	8,550	CY	12.00	102,600	15.0%	15,390	117,990
	gravel bedding	3,750	CY	16.00	60,000	15.0%	9,000	69,000
	stone protection	5,700	CY	45.00	256,500	15.0%	38,475	294,975
	topsoil seeded	1,995	SY	4.50	8,978	15.0%	1,347	10,324
	remove exist bulkhead	1,500	LF	10.00	15,000	25.0%	3,750	18,750
	Subtotal Reach C				$685,178	17.8%	$121,722	$807,000
11.	Reach D (ssp & i-wall)							
	PZ-27 (used mat'l left in pl.)	1,703,895	LB	$0.30	$511,169	25.0%	127,792	$638,961
	PZ-27 (new mat'l ssp wall)	82,965	LB	0.70	$58,076	25.0%	14,519	$72,594
	PZ-27 (new mat'l i-wall)	171,720	LB	0.70	$120,204	25.0%	30,051	$150,255
	2-C12X20.7 channel	48,000	LB	1.00	48,000	15.0%	7,200	55,200
	2 3/8"steel rod (tie backs)	70,100	LB	0.60	42,060	15.0%	6,309	48,369
	steel plate bolts & nuts	8,100	LB	1.00	8,100	15.0%	1,215	9,315
	PZ-40 (leave in place)	1,085,680	LB	0.70	759,976	20.0%	151,995	911,971
	excavation (incl both walls)	13,230	CY	8.00	105,840	15.0%	15,876	121,716
	random fill (both walls)	13,020	CY	6.00	78,120	15.0%	11,718	89,838
	reinf conc (incl. deadmen for	650	CY	437.50	284,375	25.0%	71,094	355,469
	Gate (30')	2	EA	82,500.00	165,000	30.0%	49,500	214,500
	Gate (40')	1	EA	190,000.00	190,000	30.0%	57,000	247,000
	5' wide platform	167	SY	30.00	5,010	10.0%	501	5,511
	Subtotal Reach D				$2,375,929	22.9%	$544,770	$2,921,000
11.	Reach E							
	excavation	1,430	CY	$8.00	$11,440	30.0%	3,432	$14,872
	dumped granular	3,630	CY	10.00	36,300	15.0%	5,445	41,745
	compacted imperv	11,000	CY	12.00	132,000	15.0%	19,800	151,800
	gravel bedding	2,420	CY	16.00	38,720	15.0%	5,808	44,528
	stone protection	2,310	CY	45.00	103,950	15.0%	15,593	119,543
	replace pavement	550	SY	20.00	11,000	50.0%	5,500	16,500
	remove existing stone	2,750	CY	50.00	137,500	20.0%	27,500	165,000
	Subtotal Reach E				$470,910	17.6%	$83,078	$554,000

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
11.	Reach F (T,I and Gravity Walls)							
	T-wall (100 LF)							
	excavation	860	CY	$8.00	$6,880	25.0%	$1,720	$8,600
	reinforced concrete	425	CY	437.50	185,938	25.0%	46,484	232,422
	compacted random fill	580	CY	8.00	4,640	25.0%	1,160	5,800
	coffer-dam (used PZ-27)	172,800	LB	0.45	77,760	35.0%	27,216	104,976
	dewatering	1	JOB	85,400.00	85,400	30.0%	25,620	111,020
	concrete piles	2,200	LF	30.00	66,000	50.0%	33,000	99,000
	I-wall (180+50 = 230 LF)							
	excavation	385	CY	8.00	3,080	25.0%	770	3,850
	random fill	282	CY	6.00	1,692	25.0%	423	2,115
	reinforced conc.(cap mat'l)	173	CY	437.50	75,688	30.0%	22,706	98,394
	PZ-27 (new mat'l, left)	74,520	LB	0.70	52,164	25.0%	13,041	65,205
	conc gravity wall (1150 LF)							
	excavation	1,725	CY	8.00	13,800	25.0%	3,450	17,250
	compacted random fill	9,775	CY	8.00	78,200	25.0%	19,550	97,750
	concrete	863	CY	350.00	302,050	20.0%	60,410	362,460
	Subtotal Reach F				$953,291	26.8%	$255,551	$1,209,000
11.	Revere Beach Park Dike							
	South Dike, 1970 LF							
	excavation (dike)	10,126	CY	$8.00	$81,008	20.0%	$16,202	$97,210
	compacted random fill	29,845	CY	8.00	238,760	20.0%	47,752	286,512
	compacted impervious fill	15,327	CY	12.00	183,924	15.0%	27,589	211,513
	gravel bedding	2,482	CY	16.00	39,712	15.0%	5,957	45,669
	stone protection	3,723	CY	45.00	167,535	15.0%	25,130	192,665
	topsoil & seed (12")	21,453	SY	10.00	214,530	20.0%	42,906	257,436
	topsoil & seed (6")	9,417	SY	6.00	56,502	15.0%	8,475	64,977
	random fill	33,392	CY	6.00	200,352	20.0%	40,070	240,422
	Subtotal South Dike				$1,182,000	18.1%	$214,000	$1,396,000
11.	North Dike, 1420 LF							
	excavation (dike)	6,816	CY	$8.00	$54,528	20.0%	$10,906	$65,434
	compacted random fill	16,941	CY	8.00	135,528	20.0%	27,106	162,634
	compacted imperv	11,048	CY	12.00	132,576	15.0%	19,886	152,462
	gravel bedding	1,732	CY	16.00	27,712	15.0%	4,157	31,869
	stone protection	2,599	CY	45.00	116,955	15.0%	17,543	134,498
	topsoil & seed (12")	17,196	SY	10.00	171,960	20.0%	34,392	206,352
	topsoil & seed (6")	5,992	SY	6.00	35,952	20.0%	7,190	43,142
	random fill	23,430	CY	6.00	140,580	20.0%	28,116	168,696
	Subtotal North Dike				$815,791	18.3%	$149,000	$965,000

SAUGUS RIVER

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
11.	North Closure							
	excavation (retaining wall)	570	CY	$8.00	$4,560	25.0%	$1,140	$5,700
	compacted random fill	2,690	CY	8.00	21,520	25.0%	5,380	26,900
	concrete retaining wall	339	CY	400.00	135,600	30.0%	40,680	175,280
	gravel bedding	750	CY	16.00	12,000	25.0%	3,000	15,000
	3" bit concrete	2,747	SY	16.00	43,952	25.0%	10,988	54,940
	guardrail	370	LF	20.00	7,400	20.0%	1,480	8,880
	control traffic	1	LS	10,000.00	10,000	20.0%	2,000	12,000
	sandbags	1,820	EA	5.00	9,100	20.0%	1,820	10,920
	Subtotal North Closure				$244,132	27.0%	$66,000	$311,000
11.	South Closure							
	excavation (retaining wall)	760	CY	$8.00	$6,080	25.0%	$1,520	$7,600
	compacted random fill	4,068	CY	8.00	32,544	25.0%	8,136	40,680
	concrete	620	CY	300.00	186,000	25.0%	46,500	232,500
	gravel bedding	750	CY	16.00	12,000	25.0%	3,000	15,000
	3" bit concrete	2,500	SY	16.00	40,000	25.0%	10,000	50,000
	guardrail	440	LF	20.00	8,800	20.0%	1,760	10,560
	control traffic	1	LS	10,000.00	10,000	20.0%	2,000	12,000
	mbta sandbag closure	1,000	EA	5.00	5,000	20.0%	1,000	6,000
	Subtotal South Closure				$300,424	24.6%	$74,000	$374,000
11.	Shawmut Street Stop Logs							
	excavation	360	CY	$8.00	$2,880	25.0%	$720	$3,600
	compacted random fill	200	CY	8.00	1,600	25.0%	400	2,000
	concrete	251	CY	300.00	75,300	25.0%	18,825	94,125
	gravel bedding	20	CY	16.00	320	25.0%	80	400
	center post W10x22 14'	1	EA	600.00	600	20.0%	120	720
	8"x8" white oak logs 12'	32	EA	150.00	4,800	20.0%	960	5,760
	Subtotal Stop Logs				$85,500	24.6%	$21,000	$107,000
11.	North and South Floodwalls							
	excavation	380	CY	$8.00	$3,040	25.0%	$760	$3,800
	compacted random fill	170	CY	8.00	1,360	25.0%	340	1,700
	concrete	333	CY	300.00	99,900	25.0%	24,975	124,875
	gravel bedding	90	CY	16.00	1,440	25.0%	360	1,800
	reinforced concrete	65	CY	400.00	26,000	25.0%	6,500	32,500
	SSP PZ-27 (pol.sta.- ret.wall)	36250	LB	0.70	25,375	30.0%	7,613	32,988
	topsoil & seed (6")	60	SY	6.00	360	25.0%	90	450
	Subtotal North and South Floodwalls				$157,475	25.8%	$40,638	$198,000

SAUGUS RIVER

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
11.	Reach M Gravity Wall							
	excavation	750	CY	$8.00	$6,000	25.0%	$1,500	$7,500
	compacted random fill	400	CY	8.00	3,200	25.0%	800	4,000
	gravel bedding	125	CY	16.00	2,000	25.0%	500	2,500
	topsoil & seed (6")	500	SY	6.00	3,000	25.0%	750	3,750
	concrete (gravity wall)	525	CY	300.00	157,500	25.0%	39,375	196,875
	sandbags (Carey Circle & Blvd)	2,000	EA	5 00	10,000	25.0%	2,500	12,500
	Subtotal Reach M Gravity Wall				$181,700	25.0%	$45,425	$227,000
11.	Point of Pines - 100 Year Storm							
	Reach A, Revetment							
	excavation	3,700	CY	$8.00	$29,600	20.0%	$6,000	$35,600
	gravel bedding	640	CY	16.00	10,240	20.0%	2,000	12,240
	underlayer stone	1,900	CY	35.00	66,500	20.0%	13,000	79,500
	armor stone	3,600	CY	70.00	252,000	20.0%	50,000	302,000
	Subtotal Reach A				$358,340	19.8%	$71,000	$429,000
11.	Reach B, Revetment							
	excavation	9,000	CY	$8.00	$72,000	20.0%	14,400	$86,400
	gravel bedding	1,900	CY	16.00	30,400	20.0%	6,080	36,480
	underlayer stone	5,500	CY	35.00	192,500	20.0%	38,500	231,000
	armor stone	8,800	CY	70.00	616,000	20.0%	123,200	739,200
	Subtotal Reach B				$910,900	20.0%	$182,180	$1,093,000
11.	Reach C, Revetment							
	excavation	7,200	CY	$8.00	$57,600	20.0%	11,520	$69,120
	gravel bedding	1,300	CY	16.00	20,800	20.0%	4,160	24,960
	underlayer stone	3,700	CY	35.00	129,500	20.0%	25,900	155,400
	armor stone	7,500	CY	70.00	525,000	20.0%	105,000	630,000
	Subtotal Reach C				$732,900	20.0%	$146,580	$879,000
11.	Reach D, Revetment							
	excavation	15,000	CY	$8.00	$120,000	20.0%	$24,000	$144,000
	gravel bedding	1,600	CY	16.00	25,600	20.0%	5,120	30,720
	underlayer stone	4,700	CY	35.00	164,500	20.0%	32,900	197,400
	armor stone	6,500	CY	70.00	455,000	20.0%	91,000	546,000
	Subtotal Reach D				$765,000	20.0%	$153,020	$918,000

SAUGUS RIVER

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
11.	Reach E, Revetment Under Dunes & Concrete Cap							
	excavation of sand dunes	36,000	CY	$4.50	$162,000	20.0%	$32,400	$194,400
	gravel bedding	4,700	CY	16.00	75,200	20.0%	15,040	90,240
	underlayer stone	4,300	CY	35.00	150,500	20.0%	30,100	180,600
	armor stone	9,300	CY	70.00	651,000	20.0%	130,200	781,200
	concrete	65	CY	300.00	19,500	20.0%	3,900	23,400
	reinf. bar #5	80	LF	1.00	80	20.0%	16	96
	Subtotal Reach E				$1,058,000	20.0%	$211,656	$1,270,000
11.	Reach F, Concrete T-wall							
	excavation	2,400	CY	$8.00	$19,200	20.0%	3,840	$23,040
	compacted impervious fill	550	CY	12.00	6,600	20.0%	1,320	7,920
	compacted gravel fill	1,140	CY	16.00	18,240	20.0%	3,648	21,888
	stone protection	290	CY	40.00	11,600	20.0%	2,320	13,920
	reinforced concrete	560	CY	350.00	196,000	30.0%	58,800	254,800
	vehicle gate 12'	1	EA	40,000.00	40,000	30.0%	12,000	52,000
	Subtotal Reach F				$291,640	28.1%	$81,928	$374,000
	TOTAL COST ACCOUNT 11. LEVEES AND FLOODWALLS				$39,654,417	22.0%	$8,742,509	$48,489,000

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
17.	BEACH REPLENISHMENT							
	Point of Pines - 100 Year Storm							
	Reach B							
	sandfill-from dune excavation	6,400	CY	4.00	25,600	20.0%	5,120	30,720
	Reach C							
	sandfill(from dune excavation)	7,200	CY	4.00	28,800	20.0%	5,760	34,560
	Reach D							
	sandfill-from dune excavation	3,400	CY	4.00	13,600	20.0%	2,720	16,320
	Reach E							
	sandfill(from dune excavation)	19,000	CY	4.00	76,000	20.0%	15,200	91,200
	sand fence - 4' high	1,600	LF	4.00	6,400	100.0%	6,400	12,800
	beach grass	14,000	SY	1.00	14,000	20.0%	2,800	16,800
	TOTAL COST ACCOUNT 17. BEACH REPLENISHMENT				$164,400	23.1%	$38,000	$202,000

COST ACCOUNT NUMBER	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY PERCENT	CONTINGENCY AMOUNT	TOTAL AMOUNT
19.	BUILDINGS, GROUND AND UTILITIES							
	Rice Avenue site restoration							
	remove wall	250	LF	10.00	2,500	20.0%	500	3,000
	precast concrete curb, beach	250	LF	11.00	2,750	20.0%	550	3,300
	trees	6	EA	212.00	1,272	20.0%	254	1,526
	topsoil and seed	850	SY	4.50	3,825	20.0%	765	4,590
	precast concrete curb	270	LF	11.00	2,970	20.0%	594	3,564
	shrubs (3'-4'tall)	50	EA	25.00	1,250	20.0%	250	1,500
	Lynn parking							
	pave parking lot (37,000 sf)	1	LS	45,000.00	45,000	20.0%	9,000	54,000
	shrubs (3'-4' tall)	50	EA	25.00	1,250	20.0%	250	1,500
	topsoil and seed	5,000	SF	4.50	22,500	20.0%	4,500	27,000
	trees	15	EA	212.00	3,180	20.0%	636	3,816
	Point of Pines - 100 Year Storm							
	Reaches B-F along structures site restoration							
	topsoil and seed	3,470	SY	4.50	15,615	20.0%	3,123	18,738
	shrubs (2'-3'tall)	180	EA	18.00	3,240	20.0%	648	3,888
	precast concrete curb	3,300	LF	11.00	36,300	20.0%	7,260	43,560
	Reaches B-F							
	cross overs	13	EA	7,000.00	91,000	20.0%	18,200	109,200
	Revere Beach Park Dike							
	Dike, site resoration							
	shrubs (2'-3'tall)	200	EA	18.00	3,600	20.0%	720	4,320
	trees (replace)	30	EA	212.00	6,360	20.0%	1,272	7,632
	TOTAL COST ACCOUNT 19. BUILDINGS, GROUND AND UTILITIES				$242,612	20.0%	$48,522	$291,000

APPENDIX D

COASTAL ANALYSIS

COASTAL ANALYSIS

Introduction

This section explains the coastal concerns which are important in evaluating the shorefronts along Revere Beach, Point of Pines and Lynn Harbor. It also describes coastal studies needed for design of this regional project.

Revere and Lynn are coastal communities in Massachusetts located immediately north of the cities of Boston and Winthrop. Their shorefront is divided into four separate areas; Roughans Point, Revere Beach, Point of Pines and Lynn Harbor.

Roughans Point, located just south of Revere Beach is a summer and year-round residential area fronted by bulkhead and stone revetment protection constructed by the Massachusetts Department of Public Works.

Revere Beach is crescent shaped and has a northeast-southwest orientation. It extends approximately 3.5 miles from Roughans Point north toward Point of Pines at the mouth of the Saugus River.

The Revere Beach Reservation, under the auspices of the Metropolitan District Commission, extends the full length of Revere Beach. A wide boulevard flanked by sidewalks and pavilions stretches the length of the Reservation, paralleling the beach. Various seawalls and concrete aprons along the backshore provide some protection to the pavilions, boulevard and backshore facilities during storm conditions. Bathhouses are located midway along the beach. Private residences, condominiums and some retail properties, as well as the historic MDC Police Station, interspersed with refreshment stands and restaurants border the boulevard.

The Point of Pines section is a roughly triangular shaped peninsula located at the northerly end of Revere Beach between Carey Circle and the mouth of the Saugus River. About 360 year-round residences, a school, yacht club, fire station, and two churches are located in this area which features about 3,000 linear feet of shorefront facing Broad Sound.

The geography at Point of Pines is such that the widest beach is located at its northerly end, near the mouth of the Saugus River that was built-up by accretion over the years. The southern end of Point of Pines abutting Revere Beach has no beachfront at high tide because of the erosive wave forces. Rice Avenue, a paved town road, parallels the beach and is partially protected from wave action by stone revetments and concrete walls on the southern end, and by the sandy beach and dunes to the north.

The entire shorefront area is exposed to open ocean waves coming from the east through the southeast, but is protected from direct ocean waves from the other quadrants. The area is protected from direct ocean wave attack from the northeast by Big and Little Nahant; however, storm waves do diffract around the Nahants and propagate toward the beaches. The Cherry Island breakwater and Winthrop Highlands provide some protection from southerly wave attacks.

Revere Beach and Point of Pines both suffer from long-term erosion, primarily due to extensive development of the shoreline and the existence of protective coastal structures which have limited the landward advance of the shoreline at the expense of the beach. Construction of coastal barriers has reduced the volume of littoral material in the system resulting in an insufficient supply of replenishment material. During frequent serious storms, waves break against the concrete seawalls and stone revetments which in turn reflect the wave energy, causing increased sand losses due to scouring at the toe of these structures.

Offshore Bathymetry

The offshore bathymetry is remarkably flat with the exception of a few lag deposits which are remnants of eroded drumlins. These rock outcrops can significantly alter the wave refraction patterns (Hayes, 1973).

The offshore sediment is fine-grained and is unsuitable as a source of beach nourishment. Fine sand is deposited at the southern portion of the embayment in the vicinity of Simpson's Pier. Coarse sand from Lynn Harbor is transported by tidal currents and wave action. The sediment becomes progressively finer away from the center of the embayment. Coarse sand is concentrated in the central region by the refraction of waves around the topographic high there (Hayes, 1973).

Shore History

The Metropolitan District Commission's Revere Beach Reservation was designed by Charles Eliot, a famous landscape architect, in the late nineteenth century, making Revere the nation's first public beach. With its convenient location, proximity to public transportation, and beautiful crescentic shape, it became a major bathing and amusement attraction, and one of the most popular Metropolitan Park Reservations (EIR, 1982).

Since construction began over 80 years ago, man's influence on the coastal processes at Revere Beach has steadily increased. Periods of erosion and accretion have been observed at Revere since 1900 when shoreline change information was first recorded. Around 1897, construction began at Revere Beach Reservation with two pavilions built on the backshore. Concrete aprons with stepped surfaces affronted the pavilion walls. By 1898, many other structures were built, including a police station, a bathhouse, foodstands, a wide boulevard and a promenade along the beach. In 1904, two more pavilions and the Northern Circle seawall were built. The Boston, Revere Beach and Lynn railroad was moved from the dune crest to the edge of the marsh on the backshore of the beach. Sleepers from the railroad were used in the bulkheads to protect the new pavilions. In 1910, the Eliot Circle seawall was built, and in 1914, a 1,500-foot stepped seawall was built, extending southwesterly from 900 feet south of Northern Circle (EIR, 1982).

By 1940, flooding of the backshore necessitated replacement of the standard concrete curb bordering the promenade with a concrete retaining wall. In 1949, erosion of Revere Beach from Shirley Avenue to Northern

Circle, coupled with the deposition of stones and cobbles on the beach face, had reduced Revere's attractiveness as a recreational beach. A cobble terrace had formed between Eliot Circle and Shirley Avenue despite repeated efforts to remove it. Shorefront construction limited the mobility of the shoreline and the seawall restricted the volume of sediment available to the beach. Beach grooming and street maintenance removed sand and gravel from the system, further reducing the sediment supply. Due to the eroding beach face, the backshore protective structures were damaged through exposure to destructive wave action. To prevent further erosion and protect the backshore structures, the Army Corps of Engineers recommended that the beach elevation be raised to 18 feet above mean low water (MLW). In 1954, the Metropolitan District Commission pumped about 172,000 cubic yards of sandfill dredged from an off-shore borrow area onto the beach between Revere Street and Shirley Avenue. Loss and redistribution of the material occurred during the construction operation resulting in about 90,000 cubic yards of material remaining on the beach within the area of placement. More sediment was lost during Hurricane Carol on August 21, 1954. Construction of the authorized plan was discontinued due to the high rate of erosion experienced with the material being used.

By 1968, Revere Beach was suffering from erosion which appeared to be caused by insufficient replenishment of material transported alongshore and offshore. Storm waves breaking against the backshore protective structures increased erosion due to scour of the beach face. It was again recommended that the beach elevation be raised to 18 feet above MLW and that the portion of the beach above the mean high water line be widened to an average of 185 feet by placement of suitable fill material.

The crescentic shape of the beach at the turn of the century had been transformed into smaller cyclic forms created by the spatial variability in the wave energy distribution along the beach and the limited sediment supply. The dry beach width above mean high water varies from zero in high energy areas to about 200 feet in more sheltered sections. This narrow width not only reduces the recreational attractiveness of the beach but increases exposure of the seawall to storm wave damage and overtopping.

Waves

Broad Sound is open to direct ocean waves from the east through south-southwest; however, the shallow water within Broad Sound dissipates much of the wave energy. Except for severe storm surge conditions, the waves reaching the shore are relatively small.

Wave information has been hindcast from climatological data assembled into a data base of wave parameter data by the U.S. Army Engineer Waterways Experiment Station. The wave data used for Broad Sound was developed for a location offshore of Nahant in approximately 30 feet of water.

Between 1970 and 1975, swells were present only 19% of the time. The water was calm during the remaining time. The swell wave heights were smaller than 10 feet with 44% of the waves less than 1.5 feet. The swell wave periods were less than 13 seconds with 55% of the periods between 5 and 9 seconds. Locally generated waves were present 50% of the time from 1970 to 1975. Maximum sea significant wave heights were 13 feet high and maximum wave periods reached 11 seconds; however, over 40% of the sea significant waves had periods of between 3 and 7 seconds and heights of less than 1.5 feet. Most of the locally generated waves emanate from the north through the southeast, with the largest concentration from the north. Nearly 85% of the swell is also from the north. The remaining 15% is from the east-southeast.

Using wind data from Logan Airport to hindcast wave information, and wave data developed by CERC for the Technical Report "Frequency of Coastal Flooding at Roughans Point, Broad Sound, Lynn Harbor, and the Saugus-Pines River System", wave conditions within Broad Sound were determined. The locally generated waves were generally small, less than 3 feet high with periods under 4.5 seconds. Direct ocean waves from east through southeast propogated into Broad Sound. From other directions the waves diffract around islands or headlands to reach Broad Sound. Although shallow water depths within the sound dissipate some of the deep water wave energy, waves approaching the beach can reach over 9 feet in height with periods up to 14 seconds (T.R. CERC-86-8).

On December 29, 1959 a severe storm occurred at Revere Beach. The storm, estimated to have a recurrence interval of 14 years, created a surge 9.5 feet above the National Geodetic Vertical Datum (NGVD), adjusted to 1975 mean sea level. The maximum wave height to occur within the study area was 8.6 feet with an associated wave period of 8.0 seconds.

Tidal Currents

Tidal currents measured in July and September 1972 reveal a regular distribution of peak tidal flows in Broad Sound. Peak velocities of 0.68 ft/sec to the north during flood and 1.1 ft/sec to the south during ebb were observed about one nautical mile offshore of Revere Beach in ten feet of water (MLW). The velocity distributions over a tidal period are strongly asymmetrical and peak velocities typically occur less than 10% of the time.

Sediment Transport

The changes in beach widths and composition at Revere are due to the effects of sheltering and offshore bathymetry on the wave field causing a variation in wave energy along the shoreline, which in turn, influences the rate of littoral transport. Littoral transport is the movement of sedimentary material within the surf zone by waves and currents, and is classified as either onshore/offshore or as longshore transport. Onshore/offshore transport is the movement of sediment perpendicular to the shoreline. Longshore transport is movement parallel to the shoreline. The trajectory of a sedimentary particle typically has both an onshore/offshore and a longshore component.

Wave-induced longshore currents are the principal influence of sediment transport in the coastal zone. Other factors influencing the sedimentation patterns along the beach include tidal currents, wind action, freshwater run-off and drainage, and the placement of artificial fill material; however, these factors are only significant in unusual circumstances. In comparison to wave-induced transport, the volume of sediment transported along Revere Beach by tidal currents is small except in the vicinity of Point of Pines where local hydraulics and sediment supply are in near equilibrium (Bohlen, 1979).

Sediment, suspended by breaking wave action is carried and distributed alongshore by both the component of the wave energy in an alongshore direction and the longshore current generated by the breaking wave. The direction of the longshore transport is directly related to the angle of wave approach with the shoreline. Therefore because of the variation in the angle of the wave approach, the direction of longshore transport may vary at random, but in most areas it varies seasonally. The rate of longshore transport is dependent on the angle of wave approach, duration, and wave energy. Although high storm waves generally move more material per unit time than that moved by low waves, because of their longer duration, low waves could move more sediment than storm waves over the long-term. Because reversals in transport direction occur, and because different types of waves transport material at different rates, two components of the longshore transport rate are important, the net rate and the gross rate. The net longshore movement of sediment at a given beach is the sum of the material transported by all the individual wave trains. The second component is the gross rate, the total of all material moving past a given point in a year regardless of direction. Most shores consistently have a net annual longshore transport in one direction.

Determining the direction and amount of average net and gross annual longshore transport is important in developing shore protection plans. However, it is generally not feasible to directly measure the littoral drift so the magnitude of the longshore transport is difficult to determine. Traditionally, there are three major methods for determining the rate of longshore transport. The best method is to modify the known longshore transport rate at a nearby site to local conditions. The next best method is to calculate the longshore transport from historical data showing changes in topography in the littoral zone. It is also possible to calculate a longshore component of "wave energy flux" which is related through an empirical curve to the longshore transport rate. Because calculation of wave energy flux is often easier and more consistent than researching hydrographic records and estimating changes between local conditions, the wave energy flux technique is frequently the most efficient method to use.

The wave energy flux method is based on the assumption that the longshore transport rate is dependent on the longshore component of energy flux in the surf zone, which is approximated by assuming conservation of energy of shoaling waves and evaluating the energy flux relation at the breaker position. This method tends to overestimate the longshore transport rate for higher values of the energy flux.

Using the wave energy flux method, the rate of longshore sediment transport at Revere Beach was estimated assuming that sufficient sediment was available for transport. Wave data hindcast from wave information was used to determine the wave energy. Frequency of occurrence was determined for each wave height, period, direction combination to develop a wave rose for Broad Sound. Because of differences in the angles of shoreline orientation and exposure to ocean wave action, Revere Beach was divided into four reaches in order to analyze the rate of sediment transport along the beach. The volume of erosion or accretion is dependent upon the gradient of the rate of sediment transport along the beach. Sediment is transported north and south out of the middle region resulting in accumulation of sediment at the northern end of Point of Pines and the southern end of Revere Beach. The results of the sediment transport analysis indicate that there is sufficient wave energy within Broad Sound to transport around 1,300 cubic yards of sediment to the southwest and 3,500 cubic yards to the northeast resulting in a net transport of 2,200 cubic yards to the northeast assuming sufficient sediment is available for transport. The net rate of sediment transport in the southern end of the shoreline would be about 900 cubic yards per year southward. The northern region of Revere Beach would experience a net rate of transport of approximately 800 cubic yards per year towards Point of Pines where the sediment appears to be accumulating. These low rates are due to the sheltering effects of the Nahants and the shallow water depths in Broad Sound. Because extreme storm activity is an important factor in determining the magnitude and net direction of littoral drift, especially in low energy areas where the normal wave climate has little influence on shoreline processes, the results of this analysis should be used with caution, and the littoral drift rates should be considered as a gross estimate of the actual littoral drift (Walton, 1976). However, this analysis clearly indicates that if sediment were placed along the beach, the volume in the middle region could be expected to be slowly transported north and south away from the middle.

The results of the sediment transport analysis are supported by Hayes (1973) in his evaluation of morphology and grain-size trends at Revere Beach which indicate that the predominant drift direction along Revere Beach is from south to north, He stated that this predominant direction resulted from hurricane winds and southeasterly winds that blow early during northeasters.

Bohlen (1978) also found similar results from his refraction analysis of Broad Sound. His refraction study showed that wave energy was concentrated in the areas adjacent to the bathhouse pavilion, between Beach and Revere Street, causing increased erosion of the beach in those locations. The sediments transported away from this nodal point appear to accumulate to the south in the vicinity of Eliot Circle and Roughans Point and to the north in the area affronting Oak Island Street.

As mentioned above, the incident wave field also produces an onshore/offshore component of sediment transport. Guidelines for the determination of the rates of onshore/offshore transport are even less firmly established than for longshore transport, therefore the magnitude of this component is difficult to evaluate, but it appears to be extremely limited. The rate of onshore/offshore transport is related to wave steepness, sediment size and beach slope. In general, high steep waves move material offshore; and long, low waves move material onshore.

Onshore/offshore transport appears to vary significantly with location along the beach and with tidal elevation. More sediment is transported onshore/offshore during high tide periods with maximum transport related to maximum wave energy. Historically the erosion rate has varied substantially. Over the 46-year time period from 1900 to 1946 the net losses averaged out to approximately 2,400 cubic yards per year. If the entire 62 year period of record is examined for the 13,000 feet of Revere Beach a net accretion of 39,500 cubic yards appears to have accrued However, during this period of time 172,000 cubic yards of native fill material were pumped onto the beach from directly offshore along the southern 5,000 feet of beach. So in essence, the beach actually experienced a net loss of approximately 132,500 cubic yards. When averaged out over this 62-year time frame, this equates to an annual loss of approximately 2,200 cubic yards. It should be pointed out that over this extended time period during any given year annual erosion rates have varied substantially due to seasonal changes or as a result of severe storm events. As stated in the 1968 NED report for Revere Beach, 4,000 cubic yards/year appears to be a representative average annual erosion rate for the native beach material in light of the losses that were experienced between 1900-1946 in the eroding sector. This figure is strictly an estimated average annual erosion rate and does not take into account the effects a severe coastal storm such as a 100-year event or even a Standard Project Northeaster (SPN) would have on the beach.

Transportation of Artificial Fill

The average composition of the native sediment is used to evaluate the suitability of potential borrow sand because the native textural patterns are assumed to be the direct response of sand sorting by natural processes. It is assumed that these same processes will redistribute artificial nourishment along the profile in a similar textural pattern as the native sand considering the differences between native and borrow sand texture. Sorting and winnowing action by waves, tides and currents will therefore tend to generally transport finer material seaward. Extremely fine particle sediment will be transported offshore and lost from the active littoral zone. During storm conditions, material finer than that found on the natural beach will be transported offshore to a depth compatible with its size forming flatter nearshore slopes than before placement. Fill coarser than material found on the natural beach will tend to remain on the foreshore and may produce a steeper beach, However, coarser material moved offshore during storms may not be returned to the beach during post-storm recovery periods. With time the coastal processes affecting the shoreline will distribute the artificial material in such a manner that the sedimentation patterns will resemble the native conditions and in doing so will reduce the original volume of fill placed on the beaches.

Material found in an abandoned I-95 embankment appears to be very suitable for beach renourishment with an overfill factor of about 1.01. Both the MDC and Saugus are developing plans for future use of the remaining fill (That part of the embankment remaining upon completion of the Revere Beach Erosion Control Project), such as converting it into a linear park or even restoring part of the area back into marshland. These plans have a direct effect on the quantity of sand available to be recovered from the embankment. There is also environmental interest in removing all of the I-95 fill, however this is unlikely to occur due to local opposition contending that the fill provides some measure of flood protection. (GDM, 1986)

Future Condition

It is expected that the future shoreline conditions at Revere Beach and Point of Pines will be different than those today. Currently, plans and specifications are being prepared for the Revere Beach Erosion Control Project which is anticipated to be constructed by the Corps in FY 90, pending the acquisition of local permits. The Revere Beach project consists of placing a 50-foot sandfill berm along the entire 13,000 feet of Revere Beach shoreline at an elevation of 13.5 feet NGVD (18' MLW) with a 1 on 15 seaward slope. The proposed material source is the abandoned I-95 embankment located approximately seven miles from the project site. (GDM, 1986)

Even though the Revere Beach Project is expected to be completed prior to construction of the Regional Flood Damage Reduction project, the existing without project condition for this report assumes that back to back storms may negate the nourishment of Revere Beach and therefore does not take any benefits for the Revere Beach project. The beach was only designed to provide full protection against a storm with a 2-year recurrence. The sandfill will provide some protection for more severe/ less frequent storm events. However, currently there is no definitive method of determining whether the sandfill will remain during the design storm, anSPN and as a result the conservative approach of assuming that it will not afford any substantial measure of protection during these storm events was taken. These conservative assumptions used either the existing or an eroded profile between Beach and Revere Streets (Reach B), and also at the northern 3,000 feet of beach (Reach D). The future stability of the beach was also discussed with and reviewed by Dr. Frank Bohlen, an Oceanographer familiar with coastal processes. The results of his analysis are presented in the Plan Formulation Appendix. As in the past, both reaches A&C of the beach shown on plates D17-D22 should remain stable in the future.

The beach and dunes at Point of Pines have proved effective in the past for protecting against tidal flooding. During the blizzard of 1978 (100-yr frequency event) a low point(s) (pedestrian path) in the dunes was only overtopped at the time of highest tide. Construction of the Revere Beach Erosion Control Project will add to the supply of sand for Point of Pines, most likely resulting in the trapping and deposition of sand at the northern end of Point of Pines as has been historically evident. With this in mind, it is expected that the beach and dunes at Point of Pines will maintain their current level of flood protection in the future, provided that continued trampling of the dunes at the end of each street does not eventually cause complete deterioration of the backshore dunes.

Proposed Plan of Protection

The coastal shorefront along Revere and Lynn Harbor was analyzed for wave runup and overtopping above existing and, where applicable, above proposed structures for various tide levels. The results are shown in the Hydraulics and Hydrology Appendix. Along Revere Beach the runup analysis profiles were developed from available mapping at the start of the study using beach elevations shown on 1981 and, in part, 1973 topographic mapping on Plates D17 to D22. Seawall elevations for the initial runup and overtopping analysis were available from 1977 Hydrographic mapping. More up to date profiles of the beach and seawalls, shown on Plates D23 to D31, were obtained during investigations of the Revere Beach Erosion Control Project in 1984. The updated surveys show additional profiles along the beach and seawalls, but would not significantly change the initial runup and overtopping analysis. These profiles reflect the existing conditions of the beach and seawall. Conditions should not be allowed to erode to the point where overtopping would increase along the beach resulting in increased flood damage, or increased flow into the estuary which could affect flooding in adjacent communities.

The proposed Regional Saugus River Floodgate plan for coastal flood protection at Revere Beach consists of a number of elements. First is to maintain the entire beach and seawalls from Eliot Circle to Carey Circle to existing dimensions. The authorized Revere Beach Project would effectively accomplish this requirement. Second is the construction of 3,420 feet of park dike along the southern portion of the backshore to contain floodwaters overtopping the beach and seawalls. Third is the construction of a 500 foot concrete wall along a northern segment of the backshore about 3,600 feet south of Carey Circle to create a 12 acre ponding area for containing and draining floodwaters overtopping the beach and seawall. All of these structures are intended to either prevent coastal floodwaters from penetrating any substantial distance beyond the immediate shoreline, or to direct them away from developed areas and thus prevent damages.

Proposed flood protection at Point of Pines also consists of three features. To the south, from Carey Circle to Alden Avenue, a stone revetment fronted by sandfill is proposed. Sandfill fronting the revetment would serve to protect the revetment toe from erosion, is less costly than hauling the excavated sand to a disposal site, and would coincidentally replace the beach area covered by the new revetment.

Although the existing beach and sand dunes from Alden Avenue to the northern tip of Point of Pines provide a high level of flood protection (up to a 100-yr. event if maintained) and wave heights in this area are significantly less than those at Revere Beach, the inability to accurately predict storm induced erosion precluded consideration of beach and dunes as the solitary protective feature against flooding in excess of a 100-yr.

event for this area. To increase the degree of confidence in the flood protection in this area and to protect the integrity of the Regional plan, it is proposed to construct a stone revetment under the existing line of dunes. This would decrease flood waters overtopping the backshore in the event that the dunes were breached. Because the beach fronting the proposed revetment is essential in reducing runup reaching the revetment and the backshore dunes are an important feature for maintaining beach dimensions, it is highly important that the dunes to be replaced over the new revetment be maintained and protected against erosion. Protection measures include boardwalks at the end of each street for pedestrian traffic over the dunes, a sand fence to trap sand from blowing off the dunes and the planting of beach grass to help stabilize the dunes.

To complete the flood protection at Point of Pines a concrete wall is proposed to be constructed along the Saugus River from the end of the sand dunes to the floodgate dike. Although this area is not subjected to any significant wave action, the wall height was designed based on runup from wave action, thereby providing a high degree of confidence that no overtopping would occur. Likewise, the Saugus River Floodgate was designed using runup caused by wave action in this area. (see Hydrology & Hydraulics Appendix)

The proposed features of flood protection at Lynn Harbor consist of various dikes and floodwalls. These structures present little or no change to the existing littoral processes of that area, while increasing erosion control as well as the level of flood protection.

<u>Models</u>

Recently, Dr. Nicholas Kraus and associate, Magnus Larson, of the Coastal Engineering Research Center (CERC) developed a numerical model that predicts storm induced beach erosion more accurately than previous models. This model, called SBEACH, is time dependent and is therefore applicable to the SPN design storm. Although SBEACH is not a two dimensional model, it has performed well in simulating the evolution of the beach profile and formation and movement of the main breakpoint bar in response to breaking waves. Also, this model has displayed the capability to produce beach recovery on the foreshore during post storm periods (Kraus & Larson, 1988). During Preconstruction Engineering & Design (PE&D), the New England Division plans on utilizing the services of CERC to run the SBEACH storm induced beach erosion model on both Revere Beach and Point of Pines.

SBEACH modelling can be used to help determine the stability of the beach and dunes at Point of Pines. Because of the smaller wave heights in this region of Broad Sound it is possible that SBEACH could be used to design a beach and dune system as a stand alone structure that will offer at least the same level of protection as the currently proposed plan with an equal degree of confidence. If the beach/dune dimensions developed in the modelling appear reasonable, it might prove cost effective to replace the proposed revetment/dunes alternative with a more extensive beach/dunes configuration. It is also conceivable that the revetment on the southern end of Point of Pines could be replaced with a beach/dune flood protection system. This of course depends on whether the sandfill design is less costly than the proposed revetments. Potential savings are impossible to calculate without knowing the dimensions of the protective beach/dunes design or how much of the proposed revetment may be replaced. One possible source of fill material is the abandoned I-95 embankment to be used as a borrow area for the Revere Beach Project, and where sand will be excavated for the mitigation plan (see section entitled "Transportation of artificial fill"). Also, material may be available from dredging for the floodgate structure provided subsurface explorations show that there is sufficient suitable material available. Depending on quantities of material required to develop a protective beach/dunes system an alternate material source may be required, thereby significantly adding to the construction cost of this alternative. All of these factors would be examined during PE&D.

SBEACH modelling at Revere Beach could be used to determine the stability of the authorized beach profile during various storm events, combined with high energy incident waves. The results of this model would help determine the fate of the beach during a high intensity storm such as a 500-year event or a SPN event. With this information the without project condition can be better defined and appropriate flood protection benefits could be applied to the Revere Beach sandfill if applicable. It is currently believed that the beach would have little effect in flood prevention near or above a 10-yr. frequency event. The SBEACH model is not intended to be used to design a beach/dune configuration for the purpose of flood protection at Revere Beach as is the case at Point of Pines. The high energy waves prevalent at Revere Beach would most certainly dictate a large sand dune to be placed on top of the proposed berm to provide flood protection with the same degree of confidence as the proposed project. This would require retaining walls along the backshore and would be aesthetically unacceptable to the local interests.

In the event that a beach/dunes design is the most economical alternative for providing flood protection at Point of Pines, without sacrificing the degree of confidence in that protection, the determination of the required maintenance costs for this feature becomes important. The Coastal Engineering Research Center offers numerical modelling of shoreline changes and sediment budget analysis that can help to estimate the quantities and direction of longshore transport within Broad Sound. This model, called GENESIS, would only be used if the beach/dunes alternative at Point of Pines is recommended to replace the proposed revetment in the selected plan. Because the supply of sediment to the Point of Pines shoreline comes from Revere Beach, both Point of Pines and Revere Beach would have to be modelled by GENESIS in order to adequately define the overall processes in the area. This modelling would be an extension of the sediment transport analysis completed for the Revere Beach Erosion Control Project as previously discussed (GDM, 1986).

Negotiations are ongoing between the New England Division and CERC concerning the previously mentioned modelling efforts. A preliminary proposal by CERC dated 4 January 1989 has been submitted to NED and is currently being evaluated. It should be noted that the final scope of work may differ substantially from that of the CERC proposal. The estimated cost, scope of work and schedule of modeling can be found in the Engineering & Design cost portion of this appendix under Design Branch, CE&SS.

Navigation

Presently a final report is being prepared for submission to the Office of the Chief of Engineers (OCE) proposing the establishment of a federal channel entering the Saugus River at a depth of 8-feet MLW. The 150-foot wide channel was designed to accommodate two way fishing vessel traffic. Under the General Edwards Bridge the channel narrows to 100-feet in width to pass between the bridge support structures. It should be noted that there are larger vessels navigating this waterway than those in the fishing fleet, such as a small oil tanker that provides fuel once a month for the General Electric (G.E.) plant, just west of the General Edwards Bridge. Obviously, traffic under the bridge is limited to one direction while these larger vessels are present.

The navigation opening in the tidal flood barrier was designed using information from the Saugus River Navigation Study. In an effort to minimize construction costs the width of the opening was set equal to that of the 100-foot restriction under the General Edwards Bridge. The sill of the navigation opening was set at an elevation of 13.5 feet below MLW (-18' NGVD) which is below the existing channel bottom in this area, and well below the proposed Federal channel depth. This should not create any problems for vessel traffic including the oil tankers supplying G.E, and will allow for a greater flow area and depth to drain the estuary.

Discussions with the Waterways Experiment Station (WES) and the Cape Cod Canal have led to the determination that a current of 3 knots (5.1 fps) or less would have no significant impact to navigation even though local velocities of 1.4 knots presently cause difficulty to vessels traveling under the General Edwards Bridge. Although these problems are caused by the current, it is felt that the inefficient hydraulic flows around the bridge abutments are the major cause for difficulties to navigation and not the currents themselves. It was also determined that the restriction in width did not directly cause problems to navigation. Using the 3 knot maximum velocity as a design criteria, ten flushing gates were added to the flood barrier to maintain tidal currents through the navigation opening at an acceptable level. (See Hydrologic and Hydraulic Appendix)

The cost of the entire flood barrier is extremely sensitive to the width of the opening required for maintaining acceptable tidal currents. The standards for setting the limits of acceptable currents are determined by safe navigation requirements. Although experience has determined that a 3 knot velocity limit would be safe for this channel configuration, a ship simulation model is being considered for use during PF&D because the overall project cost is affected by the tidal current limit, and safe navigation is a priority. In addition to the simulation model, a model should be run on the hydraulic flows effected by the navigation and flushing gates. This model would provide much information about the study area including information about currents and eddies through and around the navigation gates. (See Hydrologic and Hydraulic Appendix)

Dredging

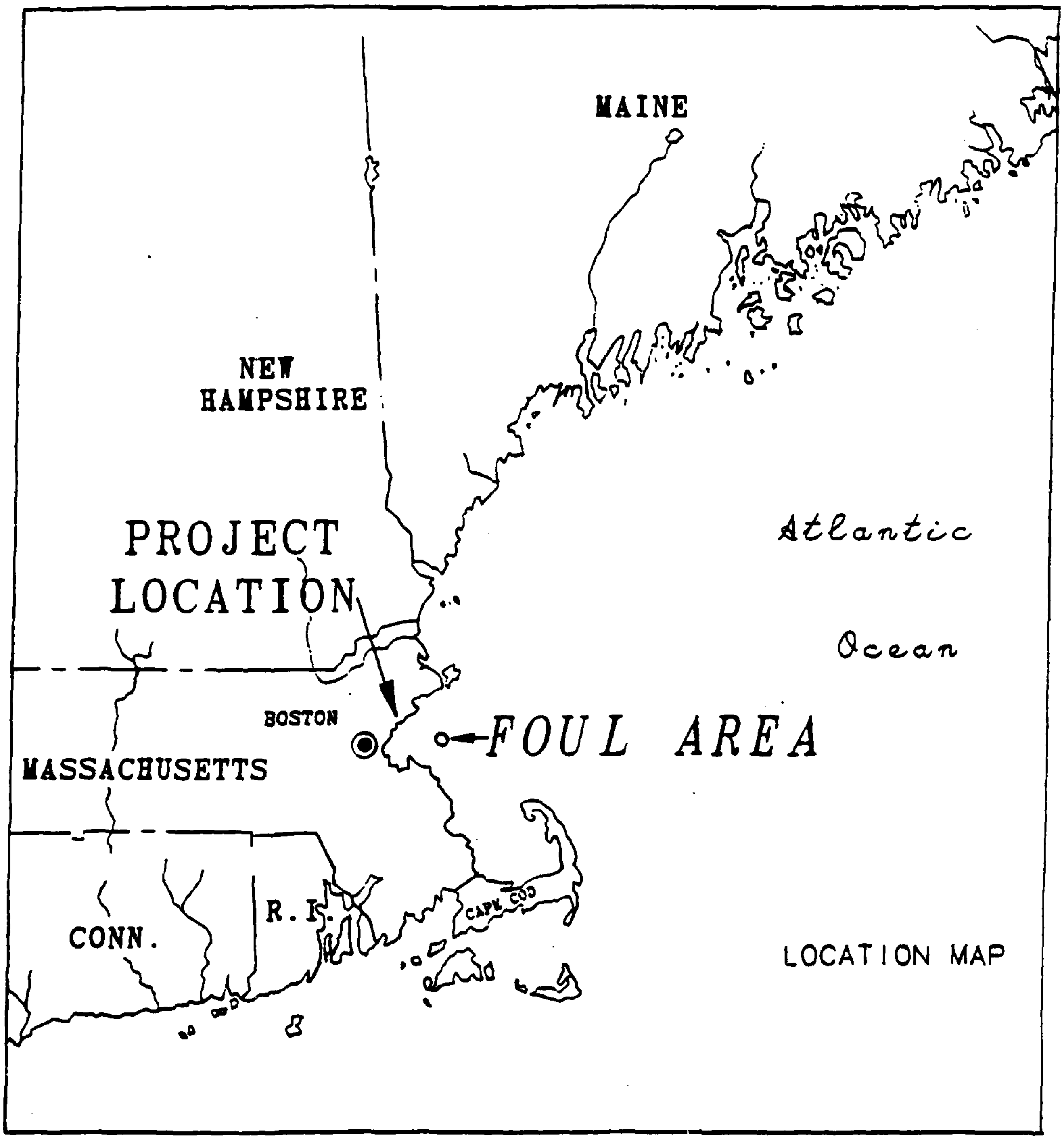
Prior to construction of the Saugus River Tidal Floodgates, the river bottom in the vicinity of the structure must be dredged down to appropriate construction grades. It is proposed that the dredging be performed by a mechanical dredge and that the material be carried and dumped by scow at the Foul Area Disposal Site, located approximately 20 miles from the project site, shown on Figures 5 & 6. Because the construction of the Floodgates would take place over a period of years, it is proposed that the dredging be performed in phases associated with the separable elements of construction. There are three dredging phases proposed.

1) Site Preparation: As shown on plate D2A, a large area surrounding gates 1-9 will be dredged to a depth of 9.5 feet below MLW (-14' NGVD). This is to allow for access of construction equipment, and being greater in depth than the proposed Federal Navigation project will also meet any temporary navigation requirements during construction.

2) Phases 1A & 1B: Prior to construction of the cofferdam at the navigation gate, the area within that dam will be dredged to a depth of 23.0' below MLW (-27.5' NGVD). Also the area of the cofferdam surrounding tainter gates 1-4 will be dredged to a depth of 17.5' below MLW (-22' NGVD). These are the proposed construction grades for these structures and are shown on plate D4. Dredging for phases 1A & 1B should be done concurrently with the site preparation dredging and prior to construction of the Phase 1 cofferdams.

3) Phases 2A & 2B: After removal of the cofferdams associated with phases 1A & 1B, the area of the cofferdams surrounding Tainter gates 5-9 and gate 10 will be dredged to a depth of 17.5' below MLW (-22' NGVD). Some of this material excavated may be used to backfill near the structures constructed in phases 1A & 1B (to be determined in PE&D).

During construction it is proposed to establish a temporary channel bypassing the cofferdam encircling the navigation gates. During that phase of construction, the cross-sectional area of the river's mouth will be significantly reduced due to the cofferdams. This reduced area will increase flows in the temporary channel during certain tide conditions and will be reviewed for any hazards to navigation. Again, use of the two previously stated models (Navigation & Hydraulic) would help determine the effects of the cofferdams and whether dredging will be required to increase the cross-sectional area of the river, thereby reducing the currents in the temporary channel. This concern is reflected in the high contingency associated with dredging quantities in the cost estimate.

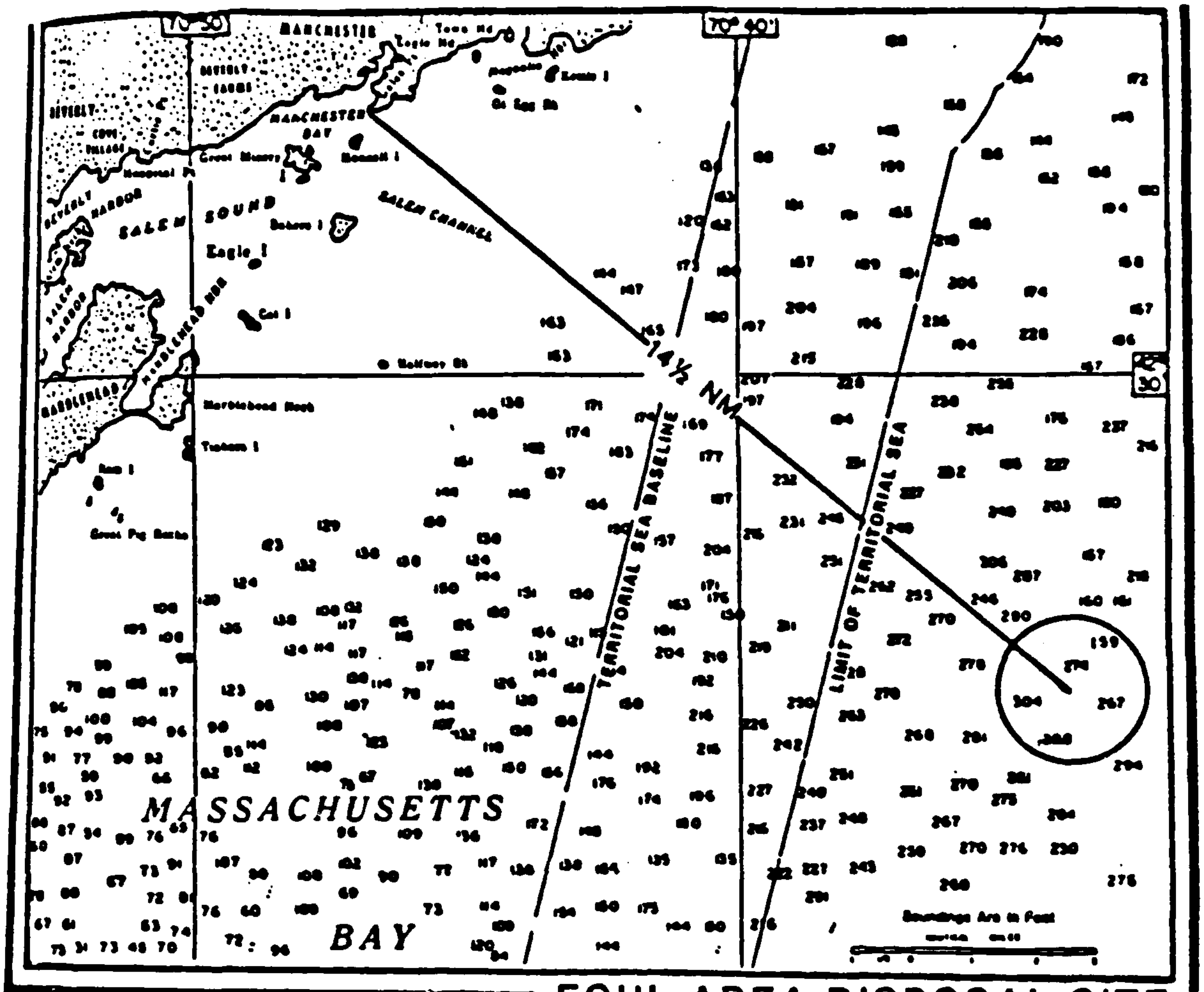


SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

FOUL AREA DISPOSAL SITE

Location Map

FIGURE 5



FOUL AREA DISPOSAL SITE

Description: This site is a circular area with a diameter of 2 nautical miles and center at 42°-25.7'N, 70°-34.0'W. From the center, the Marblehead Tower bears true 282° at 24,300 yards and Baker Island Horn bears true 300° at 24,300 yards. The authorized disposal point (within the overall disposal area) is specified for each dredging project in other project documents. Depth Range: 159 to 304 feet MLW

NOTE: The map depicts the disposal site's location in relation to landmarks. It is not intended for use in navigation.

SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

FOUL AREA DISPOSAL SITE

FIGURE 6

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APPENDIX D

ENGINEERING AND DESIGN COSTS

ENGINEERING AND DESIGN (E & D)
Regional Saugus River Floodgate Plan

The regional floodgate plan, which is the selected plan, consists of a complex system of tide gates in combination with a series of dikes, walls, stone revetment, beaches, sand dunes and associated mitigation features. The central focus of the plan are the tidal floodgates at the mouth of the Saugus River which would prevent tidal surges from entering the river and inundating interior areas. The associated project features prevent local flooding and wave overtopping into the estuary.

During feasibility studies, the Corps' New England Division (NED) identified and gathered all existing information and developed additional data and analyses to support the recommended plan. This information will provide the base from which E & D efforts will be initiated. The E & D tasks, for administrative and funding purposes, are separated into two timeframes. The first, Preconstruction Engineering and Design (PED) starts at the completion of the feasibility studies and continues up to a point when plans and specifications for the initial construction project are complete. Subsequent to PED, the design effort is funded by construction funds.

Two approaches have been considered to complete design efforts.

1. Evaluate the project as a whole throughout the design phase from initiation to construction assuming that the project will be accomplished under one construction contract.

2. Evaluate all project features concurrently but allow efforts to progress on those features which can be evaluated in a shorter time frame. This would result in a 2-phase construction effort allowing work to get started first on Phase 1, which includes the Lynn walls and dike, Pt of Pines, the mitigation site and the features behind Revere Beach. The floodgates would be constructed in Phase 2.

The primary reason for considering a two phase approach is to accelerate getting a portion of the project into construction and begin providing flood reduction benefits to Revere and Lynn as early as possible. The schedule for the flood gate portion of the project is controlled partially by a 25-month modelling effort by the Corps' Waterways Experiment Station (WES). A preliminary assessment (without a detailed CPM scheduled) of E & D costs and schedules indicated that it would take 5.5 years at a cost of $7.5 million. The initial review and reaction at NED came back with a request to look for alternatives to shorten the time frame. Two avenues were explored to reduce the time frame.

1. Allow completion of the General Design Memorandum (GDM) prior to obtaining final review of the navigation portion of the floodgate model study.

2. Breakout the floodgate from the remaining project features allowing the project to proceed toward two separate construction contracts.

The results were encouraging. By accelerating the completion of the GDM and separating the PED effort for the remaining project features out from the floodgates, plans and specs on this first phase can be completed in 3.75 years. The plans and specs on the floodgate portion would be complete in about 4.75 years. This has two advantages:

1. It maintains the momentum of the project by moving a portion into construction,

2. It provides flood reduction benefits sooner and precludes possible cost increases due to inflation.

The splitting of the project into two separate design and construction phases also carries disadvantages.

1. It will require splitting design into two separate efforts. This will probably result in added design cost although this has not been specifically evaluated. Additional design effort and attention will be required to tie the floodgate phase to the adjacent wall and dikes.

2. There is risk involved that there could be lost design effort. The second phase of the subsurface exploration is scheduled to start upon completion of the GDM which is prior to completion of the floodgate modelling studies. This could have the effect of putting the entire project back onto a schedule based on final configuration of the floodgates. This risk was assessed to be minimal since, at this stage, only final review of the final navigation model would be outstanding.

3. The construction phase of the project could be more complicated if two construction contracts are ongoing at the same time. This is particularly critical since the floodgates tie directly to adjacent project features. However, the initial construction CPM schedule indicates that the first contract will be essentially complete when the second is ready to begin. Also, the floodgates are almost totally independent of the adjacent features.

Administratively, it appears advantageous to split construction into two phases. Technically, from a design point of view, there may be advantages to keep the project intact throughout design and construction.

Summary of E & D Schedule and Costs

The schedule reflects the decision to prepare designs through plans and specifications based on the assumption that construction will occur under two separate contracts.

Phase 1. Lynn wall and dike, Revere Beach features, Pt. of Pines, and the clam flat mitigation.

Phase 2. Floodgates and Lynn PZ27 sheet pile wall near the EDIC pier.

The following table summarizes the schedule and funding requirements for completing Engineering and Design (E & D) efforts.

Schedule

TASK	FROM START OF DESIGN
Completion of GDM	1.5 years
Complete Plans and Specs - Phase 1	3.75 years
Complete Plans and Specs - Phase 2	4.75 years

Funding Requirements

Total E & D Costs	$7.228 million
Total PED /costs	$6.514 million
1 st year funding requirement	$2.826 million

The schedule is based on the assumption that funding will not be a constraint. This represents a potential obstacle since the schedule is dependent on getting a significant amount of work started in the first year, including:

1. WES modelling efforts for floodgate evaluation (See Hydrology and Hydraulics Appendix for scope), wave data and beach erosion (See Design Appendix - Coastal).

2. Surveys (hydrographic, photogrammetric, and cross-section).

3. Subsurface Explorations, and

4. In-house design and coordination activities.

The draft GDM is scheduled to be complete in 1.5 years, which, as mentioned above, is prior to final completion of the models. However, it would reflect all preliminary model results, surveys and investigations which should give a reliable update and justification of the recommended project.

Effects of Budgetary Constraints

Realistically, the E & D effort must be performed within available funding, which is $1 million for FY 90, the year design is scheduled to start. Obviously, this will not fund all the tasks which have been scheduled for the first year which, as stated above, are estimated to cost about $2.826 million. This funding requirement reflects a late start scenario and other assumptions to defer as much of the work effort as possible without affecting project completion. In comparison, an early start scenario would require in excess of $4 million in the first year. Options to deal with this shortfall include obtaining additional funds or rescheduling anticipated first year tasks into a subsequent year. The expected impact of this would be an extension of the completion schedule by a year and an increase in project management and coordination costs.

Attachments

Details of the E & D schedule and funding requirements are shown in the following attachments.

1. Scope of Work. Presents a description and cost of the tasks by organization. These were prepared by individual offices and are the basis for all schedules and funding requirements. In most cases, these were prepared based on the assumption that the project would proceed in its entirety toward one construction contract. Subsequently, the total costs were split into two separate efforts and may not accurately reflect initial programming.

2. Schedule Chart. Represents the CPM for the project schedule. See Figures 4A and 4B.

3. Project Table. A comprehensive table showing scheduling and cost information for all project tasks which are shown in the schedule chart. There are minor discrepancies between funding requirements shown in this table and the Scope of Work since last-minute changes were not reflected in the Scope.

4. Cash Flow Table. Indicates the cash flow requirements by calendar period. It is used to determine total funding requirements as well as first year and PED requirements.

E & D ESTIMATE
SAUGUS RIVER FLOOD DAMAGE REDUCTION

ORGANIZATION	TASK	COST $1,000
Water Control Br. H & WQ	Hydraulic and Navigation Models (3) Saugus R. Floodgate by WES. Duration: 25 months.	1,176
	Model Study Contract Mgmt., review, coordination, meetings, travel, etc. Duration: 25 months.	142
	Hydrology Feature Design Memo. Tidal Hydrology and Wave Overtopping (Use new waves from CERC Wave Model from beach studies).	38
	Technical coordination on Beach Erosion Model.	10
	Hydraulics Feature Design Memo - Floodgate Structure. Duration: 12 months following model completion. Define hydraulic and navigation design of floodgate.	60
	Maintain USGS tide gages for design period. Cost per year: $8,000	40
	SUBTOTALS: WES Model	1,176
	In-house	290

ORGANIZATION	TASK	COST $1000
Water Control Br. Hydrology	1. Perform a rainfall/runoff analysis of the Saugus R. watershed. Include: Unit hydrograph determination Historic Flood determination Synthetic Flood Development Project Design Flood	
	2. Interior Drainage Investigation Lynn - investigate existing drain. East Saugus - Investigate requirements of increased tide range. Revere - Investigate low flapgated areas. Ponding Area - Reinvestigate	
	3. Stage Frequency Refinement	
	4. Preparation of Appendix for GDM.	
	The above analyses will occur concurrently with preparation of the GDM. Duration is 2 years.	100
	HES coordination and consult.	30
	SUBTOTAL:	130

Design Branch Civil Engr. Sect.	1. Floodgate Structure Investigate under-river utilities, Develop layouts, sections, and quantities. Drafting: 20 drwg.	85
	2. Lynn Dike Investigate interior drainage fac. Develop layouts, sections, and quantities. Drafting: 30 drwg.	122
	3. Point of Pines Develop layouts, sections, and quantities. Drafting: 25 drwg.	97
	4. Revere Beach Park Dike Investigate interior drainage fac. Develop layouts, sections, and quantities. Drafting: 12 drwg.	76
	5. Coordination and reports	161
	SUBTOTAL	541

Design Branch Gen. Engr. Sect.	1. Input to GDM		
	Design Fee		116
	Drafting		4
	2. Prepare Concrete and Materials Design Memo.		
	Design Fee		66
	Drafting		4
	Outside Testing Laboratory		50
	3. Prepare Design Memo. - Navigation Gates, Flushing Gates and Appurt..		
	Design Fee		267
	Drafting		20
	4. Prepare Design Memo. - Walls and Miscellaneous Structures		
	Design Fee		107
	Drafting		8
	5. Prepare Design Memo. - Cathodic Protection		
	Design Fee		6
	Drafting		1
	6. Preparation of Plans and Specs		
	Design Fee		236
	Drafting		48
	SUBTOTALS:	Design	798
		Drafting	85
		Other	50

Design Branch CE & SS	1. Plot surveys (1 condition, 1 spec, and 2 predredge) in the area east of Gen. Edwards bridge. Plot x-sect at Point of Pines	12
	2. Revise and update layouts, quantities, costs and drawing for GDM. Prepare model description.	18
	3. Develop nearshore wave data base. Wave model by WES.	55
	4. Numerical modeling of shoreline change and sediment budget analysis by WES. (GENESIS)	90
	5. Numerical modeling of Storm-induced beach erosion by WES. (SBEACH)	75
	6. NED model coordination for wave, beach erosion, and shoreline change models.	15
	7. Model Coordination on navigation model	15
	8. Prepare final dredging design and quantities and cost estimate for plans and specs.	18
	SUBTOTALS: WES models	220
	In-house	78

Cost Engr. Br.	1. Summarize current cost estimate and separate main and subfeatures. Setup code of accounts.	5
	2. Develop detail IAW EM 1110-2-1301 for GDM.	10
	3. Prepare report and arrange cost growth categories.	10
	4. Breakdown cost estimate for each feature and subfeature and for federal and nonfederal costs	10
	5. Breakdown for OM&R cost.	5
	6. Prepare cost for all design mods through GDM approval.	11
	7. Prepare cost estimate through issue for bid.	11
	8. Prepare final government estimate.	11
	SUBTOTAL: Cost Est.	73
Design Branch Specifications	1. Prepare Concept Specs (35%)	7
	2. Mark up Guide Specs (65%)	28
	3. Prepare final specs (95%)	29
	4. Prepare final specs and issue	20
	5. Prepare any amendments prior to bid opening	17
	SUBTOTAL: Specs	101

Design Branch Surveys	1. Hydrographic Surveys	
	Lynn Harbor - 100 feet out from shore at 50 - foot spacing (9000 LF)	35
	Major Ditches and Waterways - x sect at 500 foot spacing	39
	Saugus River at General Edwards Bridge Soundings at 50 foot spacing plus all structures. (3500 LF)	19
	Point of Pines Beach - x sect at 50 foot spacing from seawall 500 feet out into ocean.	13
	Miscellaneous structures	9
	SUBTOTAL	115
	2. Land Surveys based on land and photogrammetric surveys. Lynn Harbor: 9000 LF, 70 ac Pt of Pines: 4000 LF, 35 ac Revere Beach: 5000 LF, 45 ac Ponding Area: 20 ac Develop surveys at 1" = 40'with 2-foot contour interval and spot elevations. Identify utilities, catch basins, manholes and drain inverts. (12 Stereo models, 16 drawings) Prepare profile along the existing Revere Beach and Seawalls.	102
	3. Saugus and Pines River Estuary	
	Perform x-sect surveys across marsh at 500-foot spacing.	210
	Photogrammetric Survey - Develop aerial photo coverage of marsh with contour mapping along all perimeter areas. Show 1 - foot contour interval between Elevations 5 to 8 feet over a 200 - foot wide band.	430
	TOTAL SURVEYS	857

Impact Anal. Br. Environmental	1. Develop mitigation specifics during GDM.	30
	2. Coordination	30
	3. Obtain CZM consistency and Water Quality Certification. Assist project sponsors to obtain State and local permits.	30
	4. Continue environmental design specifics for project development. Review of design documents.	35
	TOTAL ENVIRONMENTAL	125
Economics	1. Update damage survey to reflect current conditions in all zones.	14
	2. Recalculate all flood control benefits.	14
	3. Update transportation benefits.	4
	4. Prepare report for GDM.	7
	5. Continue coordination.	4
	6. Update recreation benefits.	7
	7. Review institutional and infrastructure factors for socio-economic impacts.	4
	TOTAL ECONOMICS	54
Cultural	1. Review project areas for potential impacts to historic resources (GDM)	10
	2. Coordinate with SHPO and ACHP.	5
	3. Coordination and Review.	8
	TOTAL CULTURAL	23

Task 1 assumes no survey or mitigation needed. If required, costs could range from $15,000 to $100,000.

Geotech Engr.	1. Subsurface exploration (GDM)	
	Contract	450
	Contract Management	30
	2. Subsurface Exploration	
	Contract	400
	Contract Management	30
	3. Prepare geotech. designs and reports for GDM.	220
	4. Prepare Design Memo - Foundations and Embankments	320
	5. Prepare input to plans and specs.	85
	SUBTOTALS: Explorations	850
	In-house	685
Construction	1. Develop Construction CPM for Phase 1 construction.	20
	2. Develop construction CPM for Phase 2 construction.	20
	3. Coordination. Included in General Coordination.	
	SUBTOTAL	40
Real Estate	1. Input to GDM.	10
	2. Revise and negotiate an LCA with the sponsor. Update appraisals .	10
	SUBTOTAL	20

If land rights are required within the estuary, a detailed study would be required at a cost of $60,000.

Proj. Ops. Br.	1. Review all major project components to assure design facilitates maintenance at a reasonable cost.	
	2. Review all easements and takings to to assure adequate access to all portions of the project. Review all agreements with the sponsor for financial responsibilities for maintenance. Review operational strategies for maintaining the flood storage area.	
	Note: Above costs included in General Coordination.	
Proj. Mgmt	Provide project management throughout the period of design. (Approx. 5 yrs.)	
	Functional - 1 1/4 persons $100,000 per year	500
	Life Cycle - 1/2 person $50,000 per year	250
	SUBTOTAL	750
Contracting	Provide support for all professional services and construction contracts.	10
Repro	Reproduce all documents associated with project.	
	GDM	10
	FDM's	20
	Plans and Specs	30
	SUBTOTAL	60
Coordination, General	General coordination by offices not actively working on a task. 25k/year x 5 years	125
	Review and prepare final documents	60

CASH FLOW TABLE

Starting	Plan Costs	Plan Income	Actual Costs	Actual Income	Ending	Plan Cumulative	Actual Cumulative	
10/1/89	351120.00	0.00	0.00	0.00	11/1/89	-351120.00	0.00	
11/1/89	367372.00	0.00	0.00	0.00	12/1/89	-718492.00	0.00	
12/1/89	372148.00	0.00	0.00	0.00	1/1/90	-1090640.00	0.00	
1/1/90	255681.00	0.00	0.00	0.00	2/1/90	-1346321.00	0.00	
2/1/90	223780.00	0.00	0.00	0.00	3/1/90	-1570101.00	0.00	
3/1/90	196059.00	0.00	0.00	0.00	4/1/90	-1766160.00	0.00	
4/1/90	208908.00	0.00	0.00	0.00	5/1/90	-1975068.00	0.00	
5/1/90	206910.00	0.00	0.00	0.00	6/1/90	-2181978.00	0.00	
6/1/90	180687.00	0.00	0.00	0.00	7/1/90	-2362665.00	0.00	
7/1/90	187410.00	0.00	0.00	0.00	8/1/90	-2550075.00	0.00	
8/1/90	139275.00	0.00	0.00	0.00	9/1/90	-2689350.00	0.00	
9/1/90	137130.00	0.00	0.00	0.00	10/1/90	-2826480.00	0.00	END 1ST YEAR PED
10/1/90	158016.00	0.00	0.00	0.00	11/1/90	-2984496.00	0.00	
11/1/90	150744.00	0.00	0.00	0.00	12/1/90	-3135240.00	0.00	
12/1/90	143892.00	0.00	0.00	0.00	1/1/91	-3279132.00	0.00	
1/1/91	163275.00	0.00	0.00	0.00	2/1/91	-3442407.00	0.00	
2/1/91	149660.00	0.00	0.00	0.00	3/1/91	-3592067.00	0.00	
3/1/91	145763.00	0.00	0.00	0.00	4/1/91	-3737830.00	0.00	
4/1/91	215688.00	0.00	0.00	0.00	5/1/91	-3953518.00	0.00	
5/1/91	264784.00	0.00	0.00	0.00	6/1/91	-4218302.00	0.00	
6/1/91	203010.00	0.00	0.00	0.00	7/1/91	-4421312.00	0.00	
7/1/91	115268.00	0.00	0.00	0.00	8/1/91	-4536580.00	0.00	
8/1/91	80762.00	0.00	0.00	0.00	9/1/91	-4617342.00	0.00	
9/1/91	77091.00	0.00	0.00	0.00	10/1/91	-4694433.00	0.00	
10/1/91	84433.00	0.00	0.00	0.00	11/1/91	-4778866.00	0.00	
11/1/91	76646.00	0.00	0.00	0.00	12/1/91	-4855512.00	0.00	
12/1/91	78804.00	0.00	0.00	0.00	1/1/92	-4934316.00	0.00	
1/1/92	82386.00	0.00	0.00	0.00	2/1/92	-5016702.00	0.00	
2/1/92	71640.00	0.00	0.00	0.00	3/1/92	-5088342.00	0.00	
3/1/92	78804.00	0.00	0.00	0.00	4/1/92	-5167146.00	0.00	
4/1/92	59396.00	0.00	0.00	0.00	5/1/92	-5226542.00	0.00	
5/1/92	101871.00	0.00	0.00	0.00	6/1/92	-5328413.00	0.00	
6/1/92	151272.00	0.00	0.00	0.00	7/1/92	-5479685.00	0.00	
7/1/92	154148.00	0.00	0.00	0.00	8/1/92	-5633833.00	0.00	
8/1/92	140196.00	0.00	0.00	0.00	9/1/92	-5774029.00	0.00	
9/1/92	146122.00	0.00	0.00	0.00	10/1/92	-5920151.00	0.00	
10/1/92	134121.00	0.00	0.00	0.00	11/1/92	-6054272.00	0.00	
11/1/92	79821.00	0.00	0.00	0.00	12/1/92	-6134093.00	0.00	
12/1/92	87423.00	0.00	0.00	0.00	1/1/93	-6221516.00	0.00	
1/1/93	74144.00	0.00	0.00	0.00	2/1/93	-6295660.00	0.00	
2/1/93	59800.00	0.00	0.00	0.00	3/1/93	-6355460.00	0.00	
3/1/93	68770.00	0.00	0.00	0.00	4/1/93	-6424230.00	0.00	
4/1/93	41775.00	0.00	0.00	0.00	5/1/93	-6466005.00	0.00	
5/1/93	48558.00	0.00	0.00	0.00	6/1/93	-6514563.00	0.00	END PED
6/1/93	84046.00	0.00	0.00	0.00	7/1/93	-6598609.00	0.00	
7/1/93	85146.00	0.00	0.00	0.00	8/1/93	-6683755.00	0.00	
8/1/93	64346.00	0.00	0.00	0.00	9/1/93	-6748101.00	0.00	
9/1/93	61896.00	0.00	0.00	0.00	10/1/93	-6809997.00	0.00	
10/1/93	54710.00	0.00	0.00	0.00	11/1/93	-6864707.00	0.00	
11/1/93	46772.00	0.00	0.00	0.00	12/1/93	-6911479.00	0.00	
12/1/93	48898.00	0.00	0.00	0.00	1/1/94	-6960377.00	0.00	
1/1/94	41866.00	0.00	0.00	0.00	2/1/94	-7002243.00	0.00	
2/1/94	36960.00	0.00	0.00	0.00	3/1/94	-7039203.00	0.00	
3/1/94	42504.00	0.00	0.00	0.00	4/1/94	-7081707.00	0.00	
4/1/94	30358.00	0.00	0.00	0.00	5/1/94	-7112065.00	0.00	
5/1/94	14806.00	0.00	0.00	0.00	6/1/94	-7126871.00	0.00	
6/1/94	24806.00	0.00	0.00	0.00	7/1/94	-7151677.00	0.00	
7/1/94	36333.00	0.00	0.00	0.00	8/1/94	-718801[illegible]00	0.00	
8/1/94	25479.00	0.00	0.00	0.00	9/1/94	-7213489.00	0.00	
9/1/94	12941.00	0.00	0.00	0.00	10/1/94	-7226430.00	0.00	
10/1/94	1300.00	0.00	0.00	0.00	11/1/94	-7227730.00	0.00	
11/1/94	0.00	0.00	0.00	0.00	12/1/94	-7227730.00	0.00	END E&D

TOTAL ENGINEERING AND DESIGN PROJECT COSTS TABLE

Name	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Resource Cost	Working Days	Resource Ident.
FY 90 PM	10/2/89	9/28/90	10/2/89	9/28/90	150020	260	PM-90
FY 90 COOR	10/2/89	9/28/90	10/2/89	9/28/90	24960	260	ALL-90
CULTURAL RESOURCE COOR	4/2/90	3/1/91	4/2/90	3/1/91	12960	240	CUL-1
UP DATE DAMAGE SURVEY	4/2/90	5/25/90	9/17/90	11/9/90	14000	40	ECON-1
WAVE DATA MODEL	6/25/90	3/1/91	6/25/90	3/1/91	55080	180	WES-1
SHORELINE CHANGE MODEL	6/25/90	3/1/91	6/25/90	3/1/91	0	180	WES-2
BEACH EROSION MODEL	6/25/90	3/1/91	6/25/90	3/1/91	75060	180	WES-3
MODEL COORDINATION CE & SS	4/2/90	3/1/91	4/2/90	3/1/91	19920	240	CE & SS-1
TIDAL HYDROLOGY (WCB)	4/2/90	3/1/91	4/2/90	3/1/91	10080	240	WCB-1
COASTAL ANALYSIS CE & SS	10/29/90	4/12/91	10/29/90	4/12/91	18000	120	CE & SS-2
GEOTECH CM	11/27/89	5/11/90	11/27/89	5/11/90	30000	120	GEB-2
COST ESTIMATE CODE OF ACCOUNT	5/14/90	8/3/90	5/14/90	8/3/90	25020	60	EST-1
MITIGATION ANALYSIS	11/27/89	10/26/90	11/27/89	10/26/90	15120	240	IAB-1
HYDROGRAHIC AND X-SECT SURVEY	10/2/89	3/2/90	10/3/89	3/6/90	325050	110	CE & SS-3
DATA COLLECTION WES MODEL	10/2/89	3/2/90	10/3/89	3/6/90	199980	110	WES-4
NUMERICAL MODEL PHASE 1	1/3/90	3/27/90	6/12/90	9/3/90	49980	60	WES-5
TOPOGRAPHIC SURVEY	10/2/89	12/22/89	10/2/89	12/22/89	102000	60	CE & SS-4
SUBSURFACE EXPLORATIONS	11/27/89	5/11/90	11/27/89	5/11/90	450000	120	GEB-1
MODEL COORDINATION (WCB)	10/2/89	4/12/91	3/19/90	9/27/91	92000	400	WCB-2
NAVIGATIONAL MODEL	10/2/89	8/31/90	10/2/89	8/31/90	100080	240	WES-6
PHYSICAL MODEL PHASE 1	10/2/89	12/22/89	12/12/89	3/6/90	49980	60	WES-7
PHOTO- GRAMMETRIC SURVEY	10/2/89	12/22/89	12/12/89	3/6/90	430020	60	CE & SS-5
FY 91 COOR	10/1/90	9/27/91	10/1/90	9/27/91	24960	260	ALL-91
FY 91 PM	10/1/90	9/27/91	10/1/90	9/27/91	150020	260	PM-91
UP DATE BENEFITS	5/28/90	8/17/90	11/12/90	2/1/91	25020	60	ECON-2
COST ESTIMATE BREAKDOWN	8/6/90	1/18/91	8/6/90	1/18/91	15000	120	EST-2
GEOTECH DESIGN	5/14/90	4/12/91	5/14/90	4/12/91	280080	240	GEB-2
PLOT SURVEY	12/25/89	3/16/90	12/25/89	3/16/90	12000	60	CE & SS-7
HYDROLOGY APPENDIX	5/14/90	8/3/90	5/14/90	8/3/90	19980	60	HYD-1
NAVIGATION MODEL DATA	9/3/90	1/18/91	9/3/90	1/18/91	200000	100	WES-13
NUMERICAL MODEL PHASE 2	3/28/90	8/14/90	9/4/90	1/21/91	150000	100	WES-10
PHYSICAL MODEL PHASE 2	3/5/90	7/20/90	9/4/90	1/21/91	200000	100	WES-11
FY 92 COOR	9/30/91	9/25/92	9/30/91	9/25/92	24960	260	ALL-92
FY 92 PM	9/30/91	9/25/92	9/30/91	9/25/92	150020	260	PM-92
SOCIAL ECONOMIC	8/20/90	9/14/90	2/4/91	3/1/91	4000	20	ECON-3
GDM COST ESTIMATE	1/21/91	4/12/91	1/21/91	4/12/91	10020	60	EST-3
MITIGATION PLAN	10/29/90	4/12/91	10/29/90	4/12/91	15000	120	IAB-2
HYDROGRAPHIC SURVEY	5/14/90	8/3/90	5/14/90	8/3/90	0	60	CE & SS-6
GENERAL ENGINEERING	5/14/90	4/12/91	5/14/90	4/12/91	120000	240	GES-1
BEACH MODEL COMPLETION	3/1/91	3/1/91	3/4/91	3/4/91	0	0	WES-8
CULTURAL APPENDIX	3/4/91	4/12/91	3/4/91	4/12/91	9990	30	CUL-2
LAYOUT & QUANTITIES CES	3/19/90	4/12/91	3/19/90	4/12/91	150080	280	CES-1
FY 93 COOR	9/28/92	9/24/93	9/28/92	9/24/93	24960	260	ALL-93
FY 93 PM	9/28/92	9/24/93	9/28/92	9/24/93	150020	260	PM-93
NAVIGATIONAL MODEL REPORT	1/21/91	11/22/91	1/21/91	11/22/91	157080	220	WES-9
ECONOMIC APPENDIX	9/17/90	10/26/90	3/4/91	4/12/91	6990	30	ECON-4
REAL ESTATE APPENDIX	10/2/89	12/22/89	1/21/91	4/12/91	10020	60	RE-1
DREDGING REQUIREMENTS	1/21/91	4/12/91	1/21/91	4/12/91	18000	60	CE & SS-8
HYDROLOGIC ANALYSIS	8/6/90	4/12/91	8/6/90	4/12/91	79920	180	HYD-2
MODEL REPORT REVIEW	4/15/91	6/7/91	9/30/91	11/22/91	50000	40	WCB-3
MODEL PRELIMINARY RESULTS	1/21/91	5/10/91	1/22/91	5/13/91	126000	80	WES-12
TIDAL HYDROLOGY APPENDIX	3/4/91	4/12/91	3/4/91	4/12/91	0	30	WCB-4
FY 94 COOR	9/27/93	9/23/94	9/27/93	9/23/94	24960	260	ALL-94
FY 94 PM	9/27/93	9/23/94	9/27/93	9/23/94	150020	260	PM-94
MODEL COMPLETION	11/22/91	11/22/91	11/25/91	11/25/91	0	0	WES-14
DRAFT GDM	4/12/91	4/12/91	4/15/91	4/15/91	0	0	ALL-1
TECHNICAL EVALUATION	11/22/91	11/22/91	11/25/91	11/25/91	0	0	ALL-2
REPRO & W P C	4/15/91	4/15/91	4/15/91	4/15/91	10000	1	REPRO-1

(Continued)

TOTAL ENGINEERING AND DESIGN PROJECT COSTS TABLE (Continued)

Name	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Resource Cost	Working Days	Resource Ident.
30 DAYS OCE REVIEW	4/16/91	5/13/91	4/16/91	5/13/91	0	20	OCE-1
ANALYSIS OF GATES	11/25/91	5/8/92	11/25/91	5/8/92	24960	120	GES-2
HYDRAULIC ANALYSIS	11/25/91	5/8/92	11/25/91	5/8/92	50040	120	WCB-5
GEOTECH CONTRACT MANAGEMENT	4/15/91	7/5/91	4/17/91	7/9/91	30000	60	GEB-5
SUBSURFACE EXPLORATIONS	4/15/91	7/5/91	4/17/91	7/9/91	400020	60	GEB-4
PREP FINAL GDM	5/14/91	5/14/91	5/14/91	5/14/91	10000	1	ALL-3
CATHODIC PROTECTION DM	5/11/92	7/3/92	2/15/93	4/9/93	8000	40	GES-5
FLOODGATE STRUCTURE DM	5/11/92	10/23/92	10/26/92	4/9/93	50040	120	GES-6
FLOODGATE FOUNDATION DM	5/11/92	4/9/93	5/11/92	4/9/93	158920	240	GEB-7
FLOODGATE DM	5/11/92	4/9/93	5/11/92	4/9/93	287040	240	GES-7
CIVIL ENGINEERING ANALYSIS	5/11/92	4/9/93	5/11/92	4/9/93	75120	240	CES-3
FLOODGATE HYDRAULIC DESIGN DM	5/11/92	10/23/92	10/26/92	4/9/93	30000	120	WCB-7
CONSTRUCTION MATERIALS DM	5/15/91	4/14/92	5/15/91	4/14/92	120000	240	GES-3
WALLS & STRUCTURES DM	5/15/91	4/14/92	5/15/91	4/14/92	65040	240	GES-4
TIDAL HYDROLOGY DM	5/15/91	4/14/92	5/15/91	4/14/92	48000	240	WCB-6
EMBANKMENT & FOUNDATION DM	7/8/91	4/10/92	7/10/91	4/14/92	200000	200	GEB-6
DESIGN ANALYSIS CES	5/15/91	4/14/92	5/15/91	4/14/92	75120	240	CES-2
COMPLETE & REPRODUCE FDM'S	4/15/92	4/15/92	4/15/92	4/15/92	10000	1	REPRO-2
COMPLETE & REPRODUCE FDM'S	4/12/93	4/12/93	4/12/93	4/12/93	10000	1	REPRO-3
OCE REVIEW	4/16/92	5/13/92	4/16/92	5/13/92	0	20	OCE-2
OCE REVIEW	4/13/93	5/10/93	4/13/93	5/10/93	0	20	OCE-3
GEOTECH DESIGN	5/14/92	10/28/92	10/29/92	4/14/93	45000	120	GEB-8
GENERAL ENGINEERING	5/14/92	1/20/93	8/6/92	4/14/93	84960	180	GES-8
COST ESTIMATES	5/14/92	1/20/93	8/6/92	4/14/93	10980	180	EST-4
LAYOUT & QUANTITIES (DIKE)	5/14/92	10/28/92	10/29/92	4/14/93	150000	120	CES-4
CZM & W Q CERTIFICATION	5/14/92	4/14/93	5/14/92	4/14/93	60000	240	IAB-3
CULTURAL MITIGATION	5/14/92	10/28/92	10/29/92	4/14/93	9960	120	CUL-3
SPEC	5/14/92	1/20/93	8/6/92	4/14/93	50040	180	SPEC-1
CONSTRUCTION CPM	5/14/92	10/28/92	10/29/92	4/14/93	20040	120	CONS-1
LCA & REAL ESTATE	5/14/92	10/28/92	10/29/92	4/14/93	9960	120	RE-2
GEOTECH	5/11/93	10/25/93	11/9/93	4/25/94	39960	120	GEB-9
GENERAL ENGINEERING	5/11/93	4/25/94	5/11/93	4/25/94	200000	250	GES-9
SPECS	5/11/93	1/17/94	8/17/93	4/25/94	50040	180	SPEC-2
LAYOUT & QUANTITIES (GATE)	5/11/93	4/11/94	5/25/93	4/25/94	90000	240	CES-5
DREDGING PLAN	5/11/93	8/2/93	2/1/94	4/25/94	15000	60	CE & SS-9
CONSTRUCTION CPM	5/11/93	10/25/93	11/9/93	4/25/94	20040	120	CONS-2
COST ESTIMATES	5/11/93	10/25/93	11/9/93	4/25/94	11040	120	EST-5
DRAFT PLANS & SPECS	4/15/93	5/12/93	4/15/93	5/12/93	0	20	ALL-4
OCE REVIEW	5/13/93	6/9/93	5/13/93	6/9/93	0	20	OCE-4
DRAFT PLANS & SPECS	4/26/94	5/23/94	4/26/94	5/23/94	0	20	ALL-5
OCE REVIEW	5/24/94	6/20/94	5/24/94	6/20/94	0	20	OCE-5
FINAL PLANS & SPEC	6/10/93	7/7/93	6/10/93	7/7/93	25000	20	ALL-6
FINAL PLANS & SPECS	6/21/94	7/18/94	6/21/94	7/18/94	25000	20	ALL-7
ADVANCE NOTICE	7/8/93	8/4/93	7/8/93	8/4/93	[illegible]	20	CONTR-1
REPRO	7/8/93	8/4/93	7/8/93	8/4/93		20	REPRO-4
ADVANCE NOTICE	7/19/94	8/15/94	7/19/94	8/15/94	1000	20	CONTR-2
REPRO	7/19/94	8/15/94	7/19/94	8/15/94	15000	20	REPRO-5
ISSUE PLANS & SPEC	8/5/93	9/1/93	8/5/93	9/1/93	2000	20	CONTR-3
ISSUE PLANS & SPECS	8/16/94	9/12/94	8/16/94	9/12/94	2000	20	CONTR-4
OPEN BIDS	9/2/93	9/29/93	9/2/93	9/29/93	1000	20	CONTR-5
OPEN BIDS	9/13/94	10/10/94	9/13/94	10/10/94	1000	20	CONTR-6
CONSTRUCTION AWARD PHASE 1	9/30/93	9/30/93	9/30/93	9/30/93	1000	1	CONTR-7
CONSTRUCTION AWARD PHASE 2	10/11/94	10/11/94	10/11/94	10/11/94	1000	1	CONTR-8

TOTAL PROJECT COSTS = $\boxed{\$7,227,730}$

APPENDIX D

OPERATION AND MAINTENANCE COSTS

Operations and Maintenance Costs

Estimated operations and maintenance (O&M) costs for both the SENE Regional Plan and Local Protection Plan are listed on the following pages. Separate cost estimates are included for the project features (e.g. Revere, Point of Pines, Lynn Harbor, Floodgate and Mitigation Site) and itemized by their individual elements (e.g. revetment, dune replacement, walls, etc.). Further, the appendix includes the O&M worksheet for the Regional Plan. The worksheet identifies the maintenance tasks associated with each project element, the tasks' annual frequency requirement, and its cost.

The maintenance tasks and their frequency reflect the intensity level needed to maintain the project in optimum condition, both in function and appearance. O&M costs are assigned for surveillance and enforcement of the estuary by project personnel. No additional staffing of the pertinent regulatory agencies is anticipated. Basin regulatory strategies are discussed elsewhere in the report.

Cost estimates are derived from the 1988 edition of the Means Catalogue or upon recent Corps experience or contracts cited in this report for similar work. Deterioration rates, such as the percentage of a wall expected to spall annually, are estimates based on NED's extensive experience with similar structures. A 30% overhead change and 20% contingency are added to the base costs. These estimated markups for overhead and contingencies are believed to be reasonable estimates for this type of work and initial investigation.

As noted on the worksheet, two operators would be required for the floodgates. Non-federal interests will assume all project operation, maintenance and replacement costs, including those associated with the operating personnel.

Estimated Annual Maintenance Costs for
Saugus River Flood Protection Project
—— Regional Plan ——

Feature	Element	Base Cost/Yr	Cost W/OH	20% Cont	Total
Revere	Park Dike	7992	10390	12468	
	Gra. Wall	419	545	654	
	Pond. Area	480	624	749	
	Tide Gate (Sales Cr.)	500	650	780	
					14700
Point of Pines	Revetment	275	358	430	
	Sand Dunes w/Fencing & Walkways	4324	5621	6745	
	Concrete Wall	1485	1930	2316	
	Landscaping	1322	1719	2062	11200
Lynn	Stone Dike	2674	3476	4171	
	Walls, Concrete	922	1199	1439	
	Walls, Steel	4700	6100	7332	12900
Flood-gate	Tainter Gates	48333	62832	75399	
	Nav. Gates	30000	39000	46800	
	Monitoring Equip.	25000	32500	39000	
	Parking/Access	1760	2288	2745	
	Dike with Plantings	930	1209	1451	
	Operators	50000	100000	120000	285400
Mitiga-tion	Inspection & Maintenance	1000	1300	1560	1600
			PROJECT TOTAL ———		325800
			SAY ———		325000

FEATURE	ELEMENT	MAIN. REQ'MT	PLATE # REF.	SIZE	UNITS	UNIT COST	JOB COST	ANNUAL JOB REQ.	COST/YR
REVERE	Park Dike	Mow Grass Dike & 8.5 Acre Acquisition	1-Item A 2-Item A	3420' X 110'	376 MSF	(1) $2.20/MSF	$ 837	4	$3,348
		Prune Shrubs	1-Item A	3420' X 110'	25.1 MSF	$30/MSF (14)	753	1	753
		Weed Shrub Bed	1-Item A	3420' X 110'	25.1 MSF	(15) $26/MSF	653	1	653
		Fertilize Shrubs	1-Item A	3420' X 110'	25.1 MSF	(16) $6.80/MSF	171	1	171
		Prune Trees	1-Item A	3420' X 110'	125 Trees	(17) $10.50/ea	1,313	1	1,313
		Fertilize Trees	1-Item A	3420' X 110'	125 Trees	(18) $13.30/ea	1,663	1	1,663
	Revetment @ Carey Circle	Herbicide Treatment	1-Item G 3-Item G	230' X 30'	1.6 Acre	(7) $200/acre	32	.33	11
		Replace Eroded Stone	4-Item G	230' X 30'	1.6 S.Y.	(19) $50/S.Y.	80	1	80

FEATURE	ELEMENT	MAIN. REQ'MT	PLATE # REF.	SIZE	UNITS	UNIT COST	JOB COST	ANNUAL JOB REQ.	COST/YR
REVERE	Concrete Gravity Wall	Repair Spalled Concrete	1-Item C 2-Item C	500 L.F. X 2' High	20 S.F.	(3) $5.15/S.F.	103	1	103
		Recaulk Wall Joints	1-Item C 2-Item C	500 L.F. X 2' High	100 L.F.	(4) $2.75/L.F.	275	.25	69
		Graffiti Removal	1-Item C 2-Item C	500 L.F. X 2' High	40 S.F.	(5) $3.00/S.F.	120	1	120
		Toe Drain Inspect & Clean	1-Item C 2-Item C	500 L.F. X 2' High	500 L.F.	(6) $ .78/L.F.	390	.10	39
		Mow Grass 10' Adj. to wall, both sides	1-Item C 2-Item C	500 L.F. X 2' High	10 MSF	(1) $2.20/MSF	22	4	88
	Ponding Area	Inspection & Debris Removal	1-Item D 2-Item D	20 Acres	2 Workers @ 8 hours	$15/Hr per Worker	240	2	480
	Tide Gate (Sales Creek)	Clean, Repair or Replace as needed	1-Item F	5' Dia. (Assumed)	1 Gate	(8) $250/Gate	250	2	500

FEATURE	ELEMENT	MAIN. REQ'MT	PLATE # REF.	SIZE	UNITS	UNIT COST	JOB COST	ANNUAL JOB REQ.	COST/YR
POINT OF PINES	Revetment	Herbicide Treatment	3-Item A 4-Item A	1300' X 30'	.9 Acre	(7) $200/Acre	180	.33	60
		Replace Eroded Stone	3-Item A 4-Item A	1300' X 30'	4.5 S.Y.	(19) $50/S.Y.	215	1	215
	Sand Dunes	Replace Eroded Dune Material	4-Item B 5-Item B	1720' X 50' (Avg. Width)	100 C.Y.	(9) $20/C.Y.	2,000	1	2,000
	Sand Fencing	Replace, Repair Broken Sections	4-Item B 5-Item B	1700 L.F.	170 L.F.	(10) $2.14/L.F.	364	1	364
	Access Walks (Timber)	Repair	4-Item B 5-Item B	50' Long X 8 Units	20 L.F.	(11) $50/L.F.	1,000	1	1,000
	Access Walks (Steel or Concrete)	Repair	4-Item B 5-Item B	30' Long X 6 Units	6 L.F.	(12) $100/L.F.	600	1	600
		Paint Steel	4-Item B 5-Item B	30' Long X 6 Units	3600 S.F.	(13) $ .50/S.F.	1,800	.2	360
	Wall - Concrete	Repair Spalled Concrete	4-Item C 6-Item C	700 L.F. X 7' High	98 S.F.	(3) $5.15/S.F.	505	1	505
		Recaulk Wall Joints	4-Item C 6-Item C	700 L.F. X 7' High	490 L.F.	(4) $2.75/L.F.	1,348	.25	337
		Graffiti Removal	4-Item C 6-Item C	700 L.F. X 7' High	196 S.F.	(5) $3.00/S.F.	588	1	588
		Toe Drain Insp. & Clean	4-Item C 6-Item C	700 L.F. X 7' High	700 L.F.	(6) $ .78/L.F.	546	.10	55

FEATURE	ELEMENT	MAIN. REQ'MT	PLATE # REF.	SIZE	UNITS	UNIT COST	JOB COST	ANNUAL JOB REQ.	COST/YR
POINT OF PINES	Landscaped Area	Mow Grass	4	3700' X 15'	56 MSF	$2.20/MSF (1)	123	4	492
		Prune Shrub Bed	4	3700' X 15'	3.7 MSF	$30/MSF (14)	111	1	111
		Weed Shrub Bed	4	3700' X 15'	3.7 MSF	$26/MSF (15)	962	1	96
		Fertilize Shrubs	4	3700' X 15'	3.7 MSF	$6.80/MSF (16)	25	1	25
		Prune Trees	4	3700' X 15'	19 Trees	$10.50/ea (17)	200	1	200
		Fertilize Trees	4	3700' X 15'	19 Trees	$13.30/ea (18)	253	1	253
	Access Gate	Repaint	4-Item D	30' X 6'	360 S.F.	$ .50/S.F. (13)	180	.25	45
		Replace/Repair Damaged Parts	4-Item D	30' X 6'	1 Gate	$100/Yr.	100	1	100

FEATURE	ELEMENT	MAIN. REQ'MT	PLATE # REF.	SIZE	UNITS	UNIT COST	JOB COST	ANNUAL JOB REQ.	COST/YR
LYNN	Dike	Mow 10' Adj. to Dike, Landside Only	7-Item A 8-Item A	3300' X 10'	33 MSF	(1) $2.20/MSF	73	4	290
		Herbicide Treatment	7-Item A 8-Item A	3300' X 60'	4.5 Acres	(7) $200/Acre	900	.33	300
		Toe Drain Insp. & Clean	7-Item A 8-Item A	3300' X 60'	3300 L.F.	(6) $ .78/L.F.	2,574	.1	257
		Replace Eroded or Vandalized Rip Rap	7-Item A 8-Item A	3300' X 60'	22 S.Y.	(19) $50/S.Y.	1,100	1	1,100
	Dike	Herbicide Treatment	7-Item B 8-Item B	1100' X 84'	2.1 Acre	(7) $200/Acre	424	.33	141
		Toe Drain Insp. & Clean	7-Item B 8-Item B	1100' X 84'	1100 L.F.	(6) $ .78/L.F.	858	.1	86
		Replace Eroded or Vandalized Rip Rap	7-Item B 8-Item B	1100' X 84'	10 S.Y.	(19) $50/S.Y.	500	1	500
	Wall - Steel	Replace Components of Cathodic System	7-Item C 8-Item	3000 L.F.	3000 L.F.	(20) $32,000/Wall	32,000	.1	3,200
		Inspect System	7-Item C 8-Item C	3000 L.F.	3000 L.F.	(20) $3,000/Insp.	3,000	.5	1,500
	Wall - Concrete	Repair Spalled Concrete	7-Item C 8-Item C	600 L.F. X 5' High	60 S.F.	(3) $5.15/S.F.	309	1	309
		Recaulk Joints	7-Item C 8-Item C	600 L.F. X 5' High	300 L.F.	(4) $2.75/L.F.	825	.25	206
		Graffiti Removal	7-Item C 8-Item C	600 L.F. X 5' High	120 S.F.	(5) $3.00/S.F.	360	1	360
		Toe Drain Insp & Clean	7-Item C 8-Item C	600 L.F. X 5' High	600 L.F.	(6) $ .78/L.F.	468	.1	47

FEATURE	ELEMENT	MAIN. REQ'MT	PLATE # REF.	SIZE	UNITS	UNIT COST	JOB COST	ANNUAL JOB REQ.	COST/YR
SAUGUS FLOOD BARRIER	Tainter Gates	Paint & Rehab	9-Item A 10, 11	50' X 15'	10 Gates	(21) $50,000	$500,000	.07	$ 33,333
		Repair, Adjust Mech. Equipment	9-Item A 10, 11	50' X 15'	10 Gates	(23) $1,500	15,000	1	15,000
	Navigation Gate	General Maintenance	9-Item B 12, 13	2-50'Sections	1 Gate	(23) $150,000	150,000	.2	30,000
	Monitoring Equipment	Maintain Gauging Station & Other Equipment	N/A	N/A	N/A	N/A	(24) 5,000	1	
		RCC Personnel Costs	N/A	N/A	N/A	N/A	$ 20,000	1	20,000
	Dike	Replace Eroded Riprap	9-Item C 14	430' X 50'	2.4 S.Y.	(19) $50/S.Y.	120	1	120
	Plantings	Prune Plants	9-Item C 14	430' X 30'	12.9 MSF	(14) $30/MSF	387	1	387
		Fertilize Beds	9-Item C 14	430' X 30'	12.9 MSF	(16) $6.80/MSF	88	1	88
		Weed Beds	9-Item C 14	430' X 30'	12.9 MSF	(15) $26/MSF	335	1	335
	Operators	(25)	N/A	N/A	2 Opers.	$50,000 (incl OH)	N/A	N/A	100,000
	Access & Parking	Repair/Repave Parking Lot & Access	N/A	1 Acre	Job	(26) $26,406	$ 26,406	.07	1,760
MITIGATION CLAM FLAT AREA	Same	Inspection & maintenance	N/A	14 Acres	Job	(27) $ 1,000	1,000	1	1,000

1. Means '88 edition - pg. 20. Based on 22" - 30" power mower.

2. Based on recent Corps contracts. Includes cost of sand along with labor and equipment for spreading.

3. Means '88 edition - pg. 22. Includes chipping, cleaning and epoxy grout. Assume that 1% of the exposed surface to be repaired annually.

4. Means '88 edition - pg. 22. Cut out old seal and recaulk with silicone. Assume that joints are 20' apart and replacement is needed every 4th year.

5. Cost based on recent Corps contracts. Assume that 2% of the exposed surface to be treated annually.

6. Based on recent Corps contracts. Landside only.

7. Based on recent Corps contracts. Repeat treatment every third year.

8. Estimate includes cleaning debris and silt in and around the structure twice a year along with parts replacement and repairs.

9. Based on recent Corps contracts. Most erosion is expected to occur during major storms.

10. Means '88 edition - pg. 94. Price for 4' high snow fence with steel posts 10' o.c. Assume that 10% of the fence will need replacement annually.

11. Assume that 5% of the walk will need repair/replacement annually at a cost of $50/L.F. Most anticipated damage will consist of loose or broken bottom slats/handrails.

12. Assume that 10% of walk will require repairs annually at a cost of $100/L.F.

13. Based on painting cost of $.50/S.F. with painting required every fifth year. Assume walkway width of 6'.

14. Means '88 edition - pg. 21. Prune shrub bed. Assume bed size of 100 S.F. with one bed per 1500 S.F.

15. Means '88 edition - pg. 21. Weed by handhoe once a year.

16. Means '88 edition - pg. 21. Fertilize shrub bed with nitrogen, potash, phosp./C.S.F., once a year.

17. Means '88 edition - pg. 21. Prune from ground. Assume one tree/3000 S.F. Prune once a year.

18. Means '88 edition - pg. 21. Fertilize trees with mix of nitrogen, potash, phosp./C.S.F. once a year.

19. Means '88 edition - pg. 58. 18" min. stone size machine placed. Assume that 0.2% of the surface will require resetting annually.

20. It is assumed that the steel sheet pile wall will employ a sacrificial anode system. According to a local contractor specializing in these systems, a $3,000 engineering inspection of the system will be required every two years. In addition, the system will have to be replaced at 10 year intervals at a cost of $32,000.

21. Tainter gates can be properly maintained through a comprehensive rehabilitation program undertaken at 10 to 15 yr. intervals. Work typically includes sandblasting, repainting, repair of damaged parts, and replacement of other components suspectable to wear. Other Corps Districts and Divisions report good results from this practice; only routine inexpensive maintenance is required between rehab work.

SENE maintenance costs for miter and tainter gates are based on recent work done in these other Districts and Divisions as summerized below.

District	Water Env.	Gate Type	Maintenance	Cost/Gate	Comment
Norfolk	Salt/Fresh	Miter Gate on lock system 30' x 50' leaf, 20-25 yrs. old.	Painting & Rehab every 10 to 15 yrs (gates removed)	$ 80,000 ('88)	Cost is relatively low considering scope of work & gate size. Gate size comparable to SENE.
Nashville	Fresh	Miter Gates Lock system var. sizes	Paint & Rehab every 15 yrs	$ 40,000 $120,000	District reports that cost is highly variable and is reluctant to quote an avg. fig.
Vicksburg	Fresh	Tainter Gates for dams, 50' x 35'	Paint & Rehab in '78.	$ 55,000 ('78)	Gate cost @ todays prices would be around $77,000 (@ 4% inflation). Note gate height is 35' vs 15' for SENE.
Huntington	Fresh	Miter Gates for locks 65' x 25' leaf	Sand blast & paint in place; also minor rehab	$295,000 ('87)	District notes that contractors price was high.
Huntington	Fresh	Tainter Gates for dams 110' x 30' - 25 yrs. old	Sand blast & paint twelve gates. Also some minor rehab.	$ 91,700 ('87)	These are much larger gates than those proposed for SENE. District also reported that a major cable repair was undertaken in 1978 at a cost of $1,000,000 for nine gates.

Los Angeles	Fresh	Tainter Gates	Paint gates at 5 yr. intervals	$ 20,000 ('86)	
Jackson-ville	Salt	Tainter Gates	Sand blast, paint & minor rehab. of machinery, 7 gates in all	$ 43,000 (recent contract)	
District	Water Env.	Gate Type	Maintenance	Cost/Gate	Comment
New Orleans	Fresh	Miter Gates for locks 50' x 37' leaf	Paint 10-15 yrs. & rehab.	$250,000 ('86)	Approximately the same size as the SENE gate. Note that cost is comparable to Huntington contract.
Seattle	Fresh/Salt	Miter Gates	Paint, over-haul, & re-place damaged parts every 20 yrs.	$840,000 (recent contract)	This cost reflects major rehab work.
Seattle	Fresh/Salt	Tainter Gates 32' x 10'	Paint & Rehab 6 gates	$ 83,000 (recent contract)	Cost is relatively high for gates this size.
Walla Walla	Fresh	Miter Gates for Nav. lock 43' x 55' leaf	Paint & Rehab every 4-5 yrs	$100,000 ('86)	
Walla Walla	Fresh	Tainter Gates for dam, 50' x 50', 20 yrs old	Paint & Rehab 6 gates	$ 50,000 ('86)	
Rock Island	Fresh	Miter Gates 110' width	Paint every 15 yrs.	$ 20,000/ $ 30,000 (recent contract)	This represents only a rough estimate... appears too low.
Rock Island	Fresh	Tainter Gates various types	Paint tainter gates every 15-20 yrs., 20 gates tot. Also, rehab as needed	$ 50,000 (recent contract)	

Baltimore	Fresh	Curtain Gates 8 @ 18' x 12' Miter Gates 12 @ 13' x 9'	Gates were overhauled in '83 for 1st time since installation, includes re-painting	$ 19,000 ('83)	Cost not applicable to SENE since these gates are smaller. Also, curtain gates are designed differently.
Little Rock	Fresh	Tainter Gates 50' x 30'	Repaint, rehab. 15 gates every 15 years.	$ 57,000 ('86)	
Pittsburgh	Fresh	Tainter Gates 110' x 30'	Repaint, rehab. 2 gates	$100,000 (recent contract)	

22. Includes rewinding motors, replacing bearings, adjusting limit switches, replacing/adjusting cables etc. Most of the annual maintenance should be limited to those components which contribute to the operation of the tainter gates, not the gate itself. The gate proper will be maintained through periodic rehabilitation contracts as noted above.

23. Based on recent rehabilitation work done at other districts; see footnote #21. The rehabilitation costs for miter gates at other districts vary widely, even more so than for tainter gates. A conservative contract cost of $150,000 is assumed with work done at 5 yr. intervals.

24. Monitoring Equipment:

Basin and atmospheric conditions will be monitored by the equipment listed below. All information will be relayed to a control center for analysis.

Equipment List:

Ocean level gauge
Harbor level gauge
Saugus River discharge meter
Wind direction indicator
Wind velocity indicator
Barometric pressure gauge
Rainfall gauge
Upper basin level gauge
Data collection platforms (to relay information to control center)
Gauging station

Yearly Maintenance Costs

Gauging station - $2,500.
Other equipment - $2,500.

Control center personal costs (including inspections) - $20,000.

25. Two full-time personnel will be required for barrier operation. Their primary responsibility will be manning the gates during the anticipated two to three closings per year including "close calls". Certain contingencies require two people to assure uninterrupted operation during these critical periods. For example, a lengthy event may necessitate rotating shifts between the two operators, or one of the operators may be unavailable during an event. It may be argued that employees from other projects could provide temporary service during an emergency but past experience suggests this is not feasible. A major event usually requires full time participation of all available trained personnel. In fact, many employees find it necessary to work multiple shifts to keep pace with the emergency. A case in point concerns the Corps flood control efforts during the April 87 rainstorm. Each dam site is staffed by two experienced people. However, as the storm progressed several sites required emergency backup help from office staffers who themselves were already fully occupied by other flood control priorities. Undoubtedly, reduced staffing levels would have undermined what proved to be a successful effort.

Other operator duties include normal maintenance, interfacing with the public and agency officials, data collection, managing rehabilitation and repair work, security, etc. These duties are broken down by hours as follows:

A. Maintenance Duties:

(1) Equipment testing & inspection:
e.g. gate testing, visual inspection of hydraulic, mechanical & utility components for damage, leaks, etc. Say 1 hr/day or 240 hr/yr.

(2) Routine maintenance jobs:
e.g. semi-annual gate greasing, minor painting of facility, sweeping and cleaning access areas, grass cutting, cleaning and maintaining electrical equipment, changing filters and lubricants in engines, trouble shooting minor mechanical or electrical problems, replacing or cleaning components of the cathodic protection system, maintaining heating/cooling system, replacing lights and gauges when necessary, snow removal. Say 3 hr/day or 720 hr/yr.

(3) Security:
Project borders both a highly populated area and an ecologically sensitive saltmarsh. As such, regular security checks will be needed. The basin area will be routinely monitored for activities which mayh compromise the effectiveness of the project, e.g. fill activities which reduce basin storage area. Additional time will be spent reporting and providing written documentation of these activities to appropriate authorities. Say 2 hr/day or 480 hr/yr.

Total = 1440 hr/yr.

B. Administrative Duties:

(1) Coordinate maintenance contracts:
Workload in this area will be highly variable. Assume it will average out to about 2 hr/day or 480 hr/yr.

(2) General public coordination:
Includes phone calls, meetings with private groups, public tours, public meetings/hearings, responding to written inquiries or comments. Preparation and distribution of brochures. Say 2 hr/day or 480 hr/yr.

(3) Coordination with other agency officials:
Includes checking, recording and disseminating physical data such as stream flow, tides, etc., rain totals, barometric pressure, wind speed, temperature, etc. Also, monitor information as part of the "Tide Watch" program. Also, cooperate with agencies such as MDC, Corps, EPA, FWS, Conservation Commissions, at meetings or requests for information. Say 5 hr/day or 1200 hr/yr.

Total = 2160 hr/yr

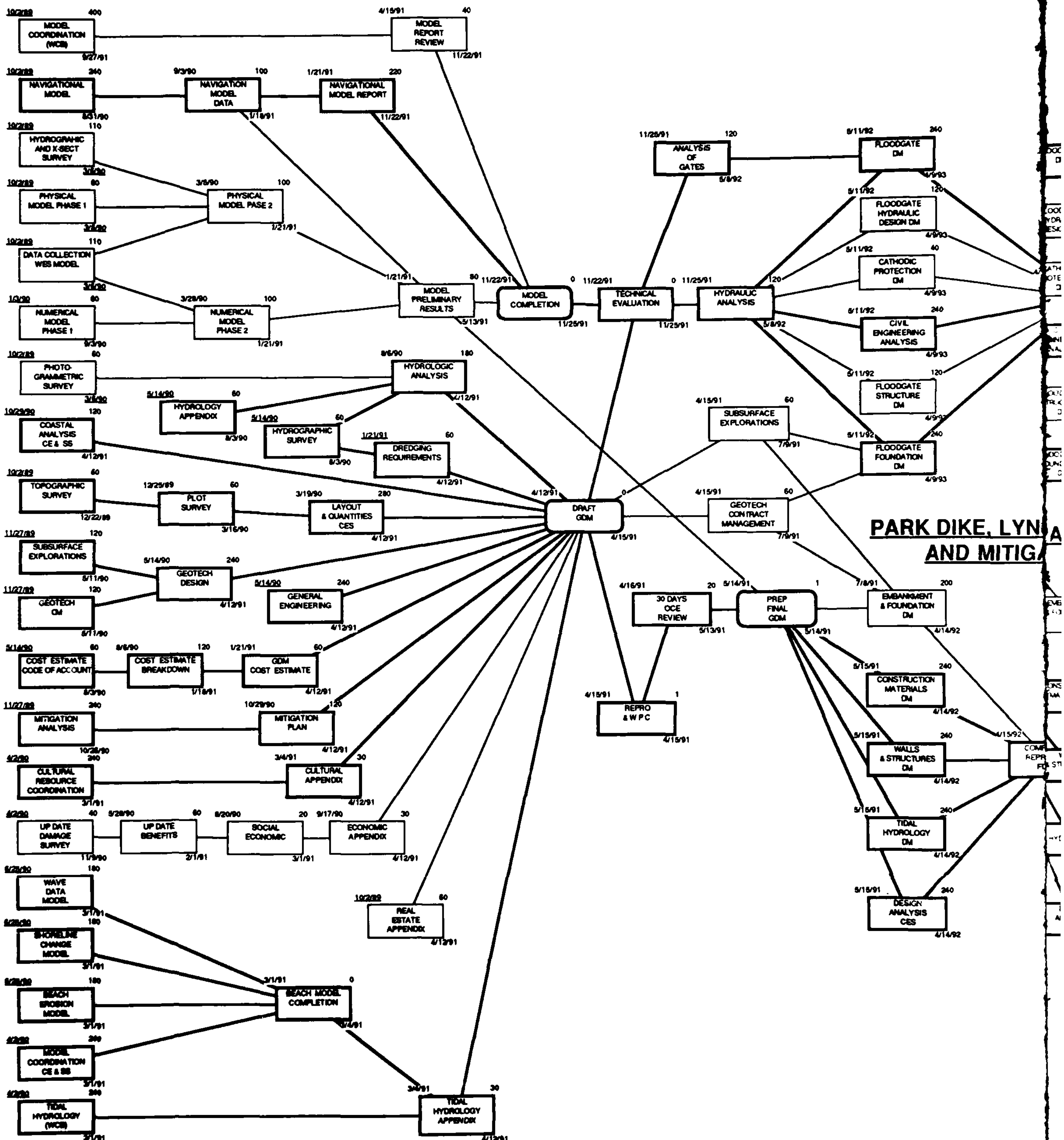
Total Maintenance & Administrative - 3600 hr/yr. Does not include vacation, sick, or overtime.

26. Assume that a one acre parking/access area will be required. This area will be repaved every 15 years. Assume that prior to repaving 10% of the area will require new base and binder. Costs are based on 12" base coarse, 1-1/2" binder, and 2" overlay. Costs derived from Means '88 edition - pgs. 55 & 65.

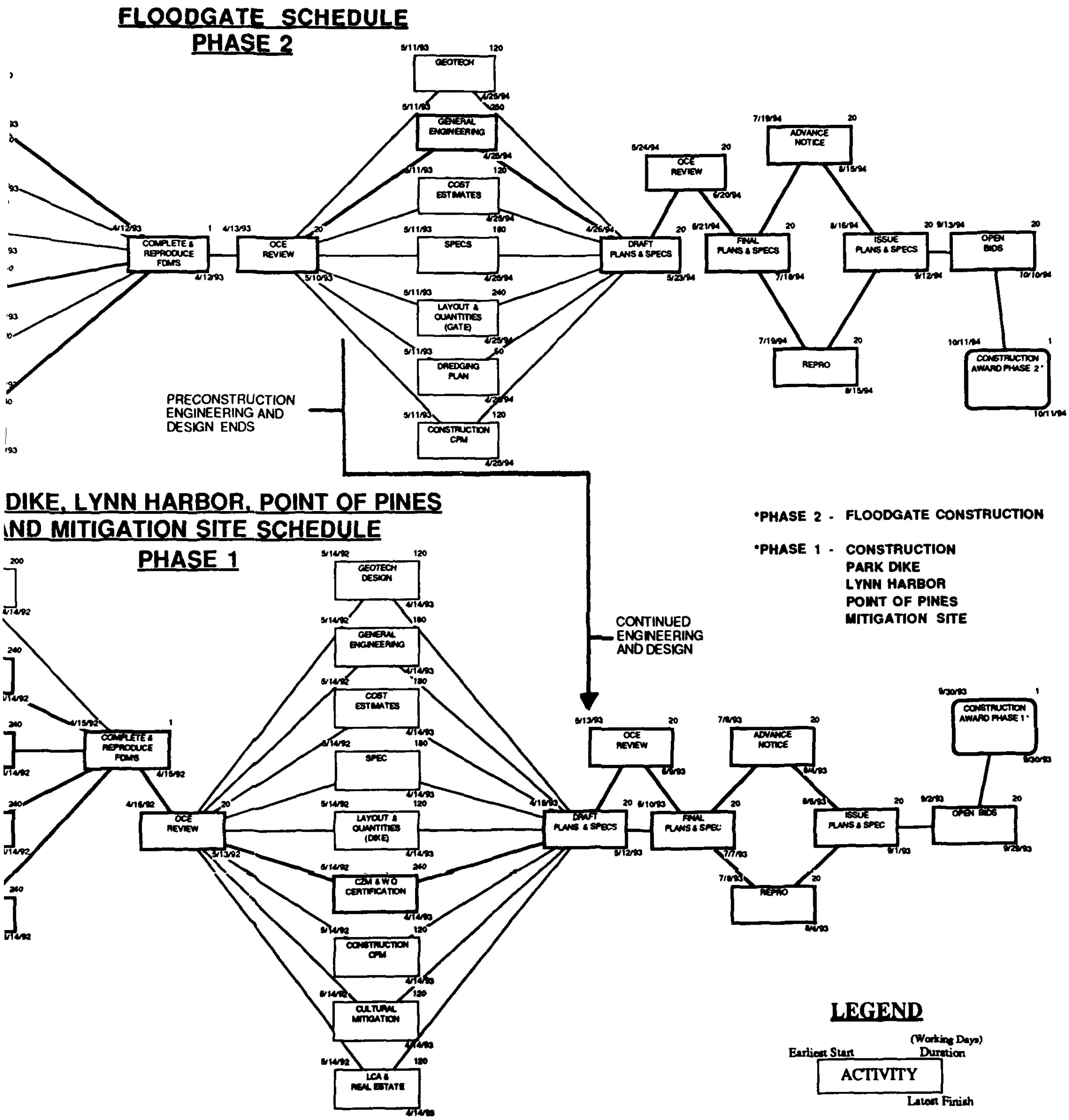
27. Mitigation area maintenance includes policing the area and cleaning up debris several times a year, maintenance of any eroded sections, removal of any flow restrictions, and consultant fees associated with any marsh productivity problems.

O&M PLATE AND ITEM REFERENCES

Plate Reference	Item Reference	Report Plate	Description
1,2	A	D-11	Revere Park Dike
1,2	C	D-21	Ponding Area Wall
1	D	D-21	Ponding Area
1	G	D-9,10	Revetment-Carey Circle
1	F	D-17	Sales Creek Tide Gate
3,4	A,B	D-9,10	Point of Pines Revetment Reaches B to D
3,4	G	D-9,10	P.O.P. Revetment, Reach A
4,5	B	D-9,10	P.O.P. Revetment, Reach E
4,6	C	D-9,10	P.O.P. T-Wall, Reach F
4	D	D-9	P.O.P. Access Gate
7,8	A	D-5,6,8,15	Lynn Reaches B&C Dike
7,8	B	D-6,7,8,15	Lynn Reach E Dike
7,8	C	D-6,8,15	Lynn Reach D Walls
9,10,11	A	D-2,2A,3	Flushing Gates
9,12,13	B	D-2,2A,3	Navigation Gate
9,14	C	D-2,2A,4	Floodgate Dike



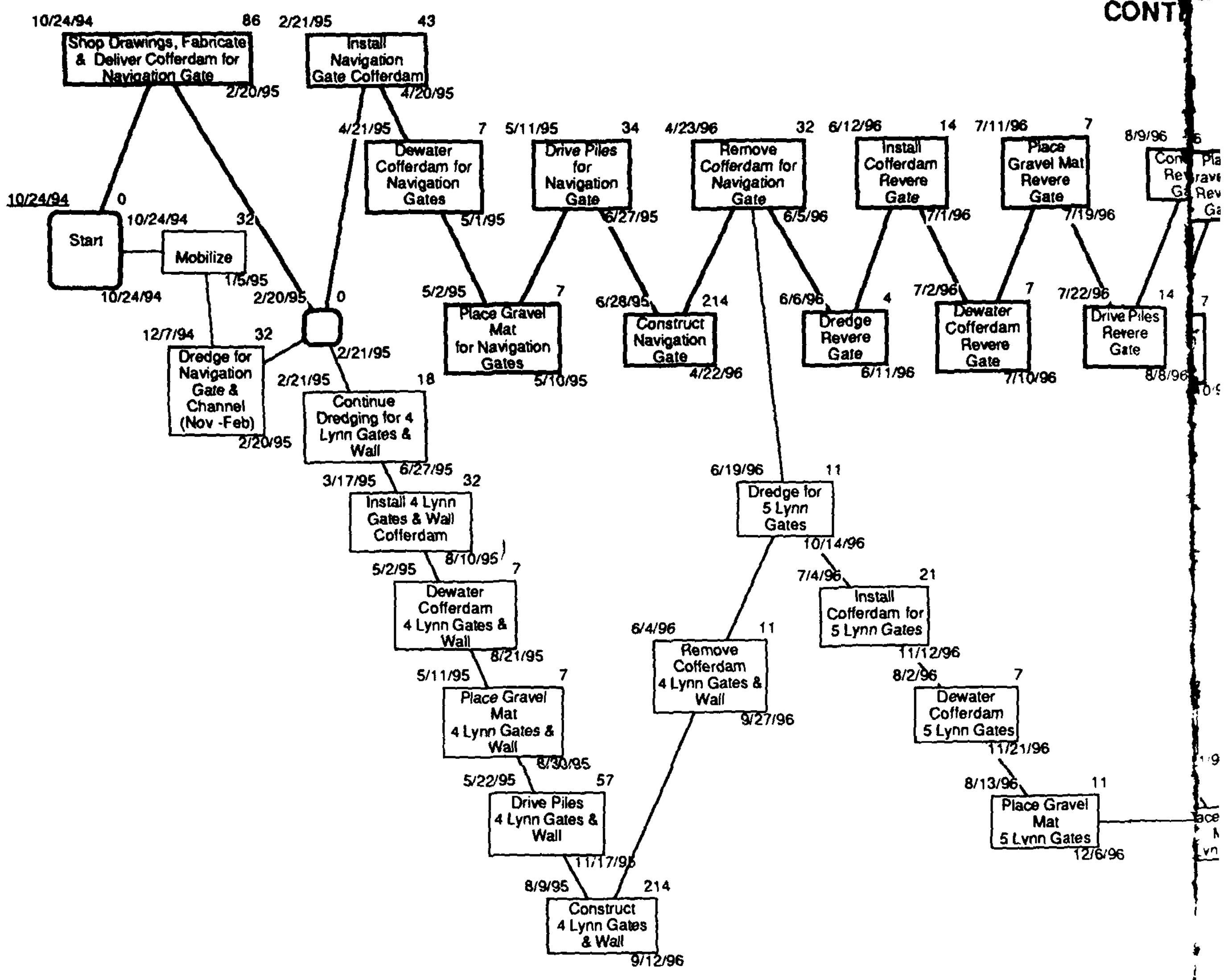
PARK DIKE, LYN
AND MITIG
MODEL COORDINATION (WCB)
MODEL REPORT REVIEW
NAVIGATIONAL MODEL
NAVIGATION MODEL DATA
NAVIGATIONAL MODEL REPORT
HYDROGRAPHIC AND X-SECT SURVEY
PHYSICAL MODEL PHASE 1
PHYSICAL MODEL PASE 2
DATA COLLECTION WES MODEL
NUMERICAL MODEL PHASE 1
NUMERICAL MODEL PHASE 2
MODEL PRELIMINARY RESULTS
MODEL COMPLETION
TECHNICAL EVALUATION
HYDRAULIC ANALYSIS
ANALYSIS OF GATES
FLOODGATE DM
FLOODGATE HYDRAULIC DESIGN DM
CATHODIC PROTECTION DM
CIVIL ENGINEERING ANALYSIS
FLOODGATE STRUCTURE DM
FLOODGATE FOUNDATION DM
SUBSURFACE EXPLORATIONS
GEOTECH CONTRACT MANAGEMENT
PHOTO-GRAMMETRIC SURVEY
HYDROLOGIC ANALYSIS
HYDROLOGY APPENDIX
HYDROGRAPHIC SURVEY
DREDGING REQUIREMENTS
COASTAL ANALYSIS CE & SS
TOPOGRAPHIC SURVEY
PLOT SURVEY
LAYOUT & QUANTITIES CES
DRAFT GDM
SUBSURFACE EXPLORATIONS
GEOTECH DESIGN
GEOTECH DM
GENERAL ENGINEERING
30 DAYS OCE REVIEW
PREP FINAL GDM
EMBANKMENT & FOUNDATION DM
COST ESTIMATE CODE OF ACCOUNT
COST ESTIMATE BREAKDOWN
GDM COST ESTIMATE
REPRO & W P C
CONSTRUCTION MATERIALS DM
MITIGATION ANALYSIS
MITIGATION PLAN
WALLS & STRUCTURES DM
CULTURAL RESOURCE COORDINATION
CULTURAL APPENDIX
UP DATE DAMAGE SURVEY
UP DATE BENEFITS
SOCIAL ECONOMIC
ECONOMIC APPENDIX
TIDAL HYDROLOGY DM
WAVE DATA MODEL
REAL ESTATE APPENDIX
DESIGN ANALYSIS CES
SHORELINE CHANGE MODEL
BEACH EROSION MODEL
BEACH MODEL COMPLETION
MODEL COORDINATION CE & SS
TIDAL HYDROLOGY (WCB)
TIDAL HYDROLOGY APPENDIX



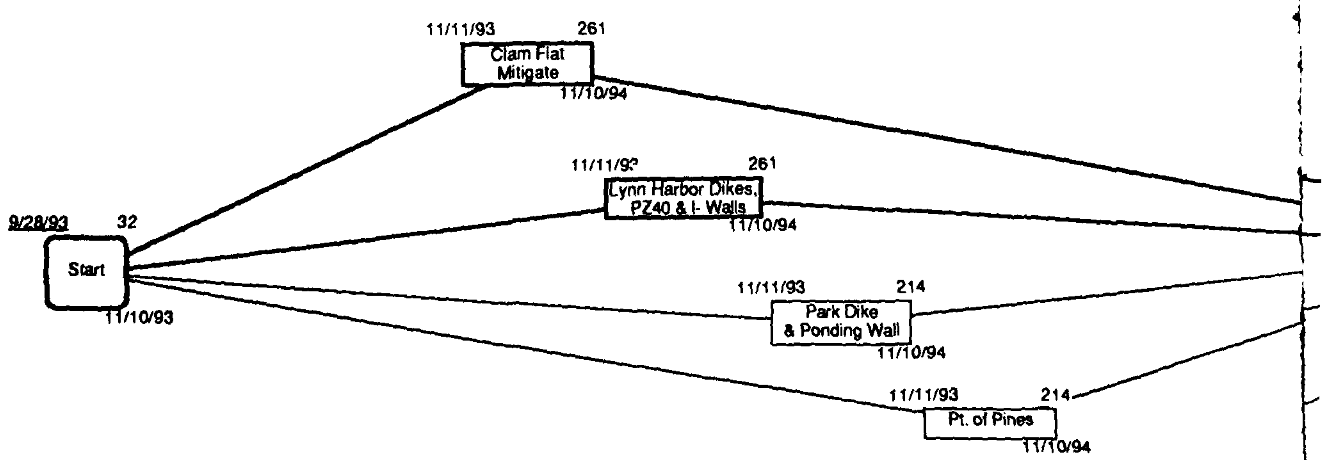
REGIONAL FLOODGATE PLAN
ENGINEERING AND DESIGN SCHEDULE

FIGURE 4A

FLOODGATE
CONT

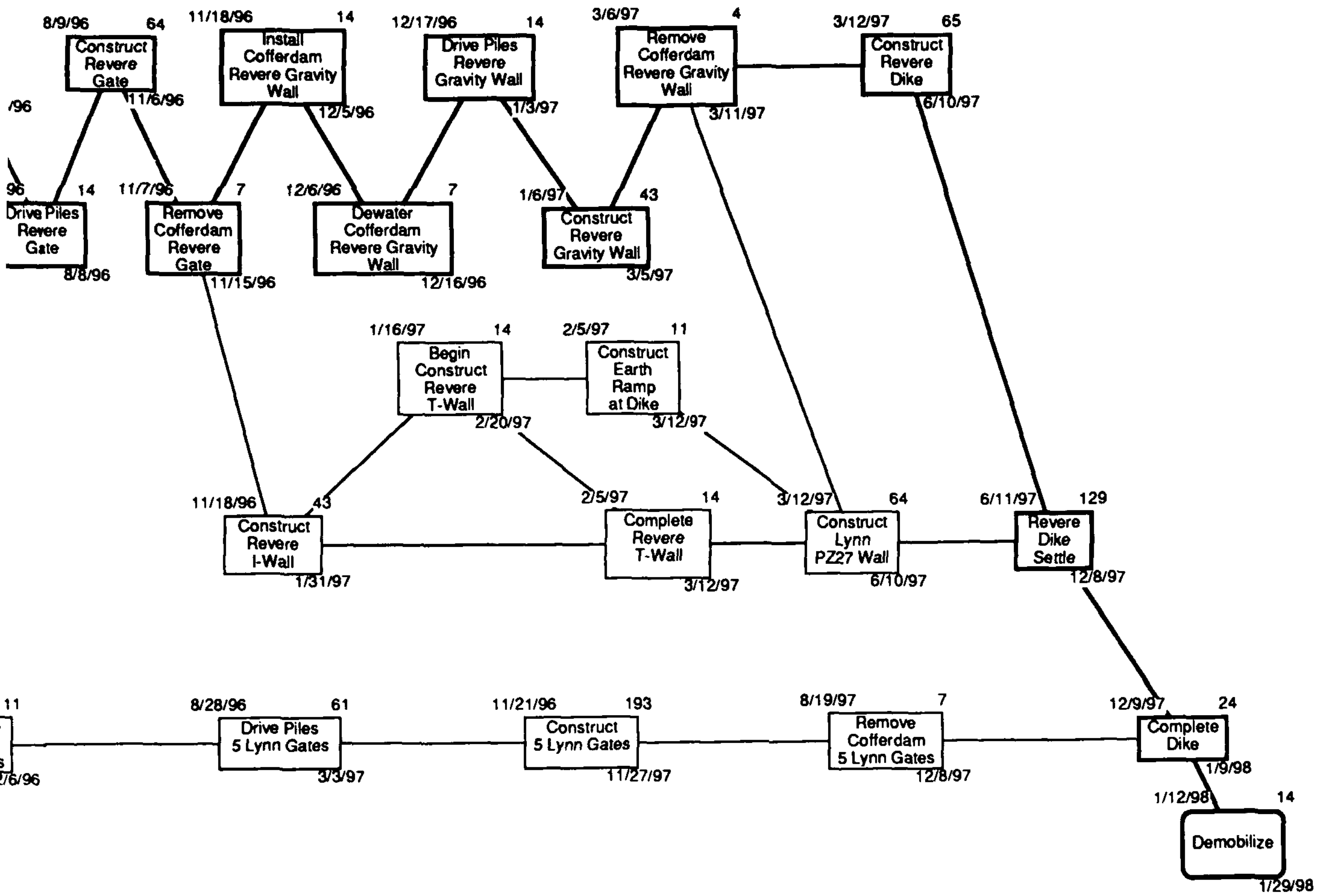


PARK DIKE, LYNN HARBOR, POINTS OF
CONTRA



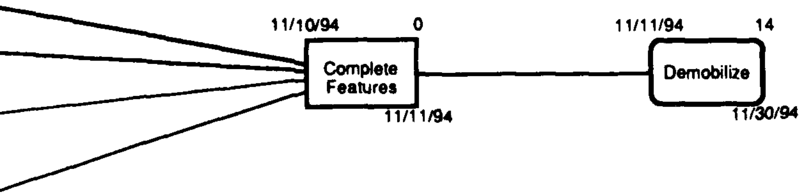
)DGATE SCHEDULE

CONTRACT 2



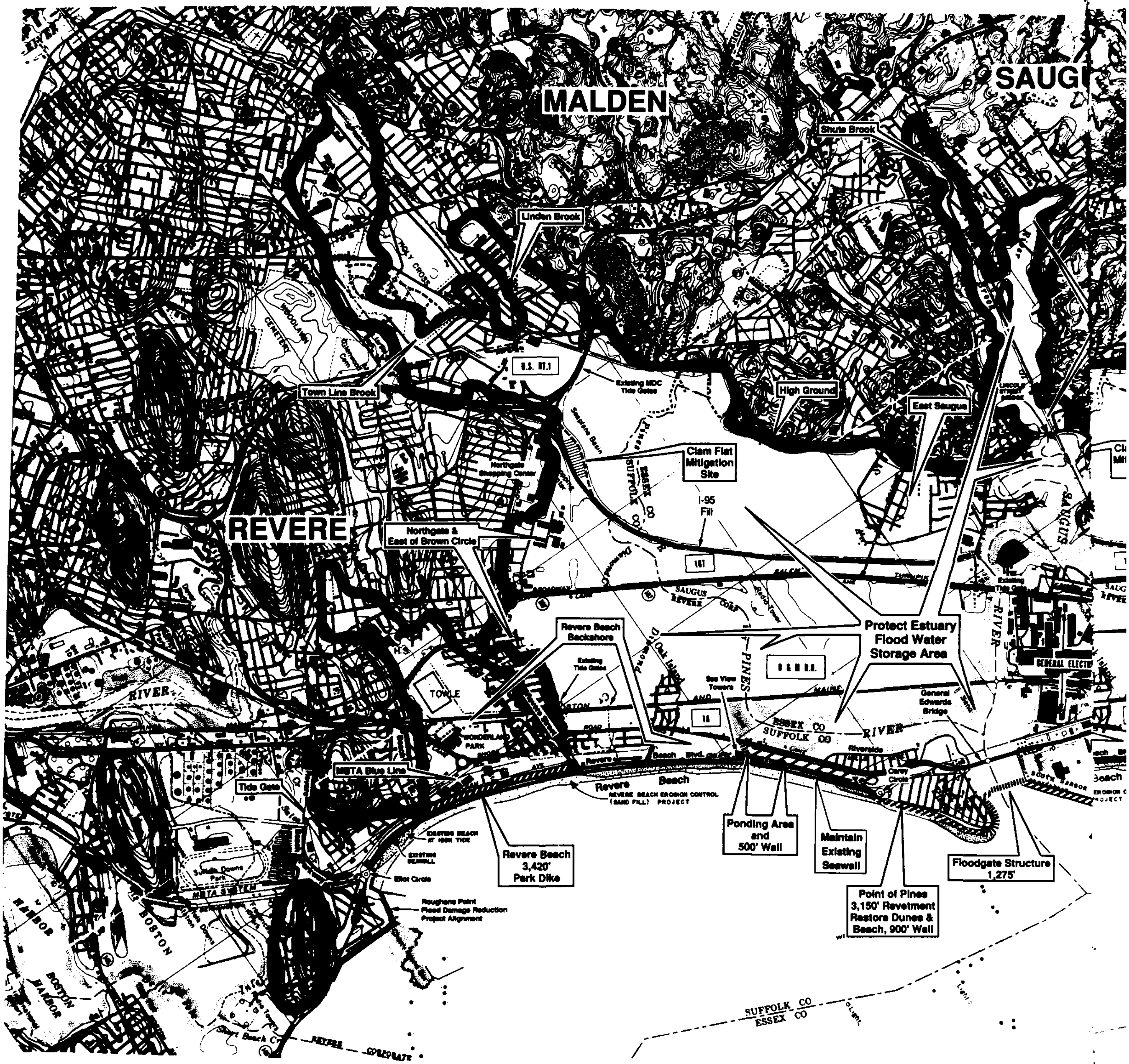
TS OF PINES AND MITIGATION SITE SCHEDULE

CONTRACT 1

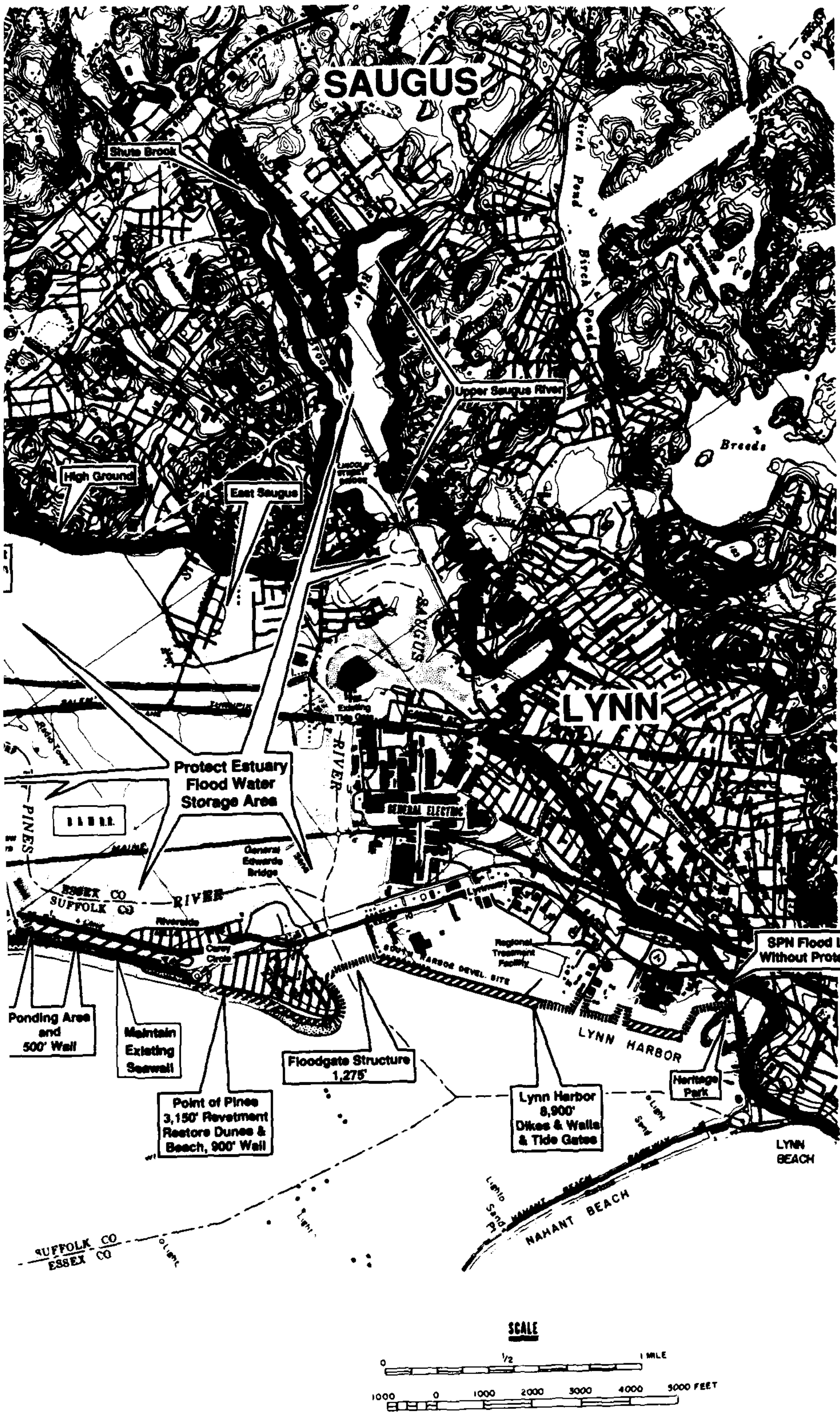


REGIONAL FLOODGATE PLAN
CONSTRUCTION SCHEDULE

FIGURE 4B


MALDEN
SAUG
REVERE
Shute Brook
Linden Brook
Town Line Brook
High Ground
East Saugus
Clam Flat Mitigation Site
I-95 Fill
Northgate & East of Brown Circle
Protect Estuary Flood Water Storage Area
Revere Beach Backshore
General Edwards Bridge
Sea View Towers
MBTA Blue Line
Tide Gate
Revere Beach 3,420' Park Dike
Ponding Area and 500' Wall
Maintain Existing Seawall
Floodgate Structure 1,275'
Point of Pines 3,150' Revetment Restore Dunes & Beach, 900' Wall
Revere Beach
REVERE BEACH EROSION CONTROL (SAND FILL) PROJECT
Roughans Point Flood Damage Reduction Project Alignment
Eliot Circle
GENERAL ELECTRIC
TOWLE
WONDERLAND PARK
U.S. RT.1
SUFFOLK CO
ESSEX CO
BOSTON HARBOR
RIVER

U. S. ARMY



LEGEND

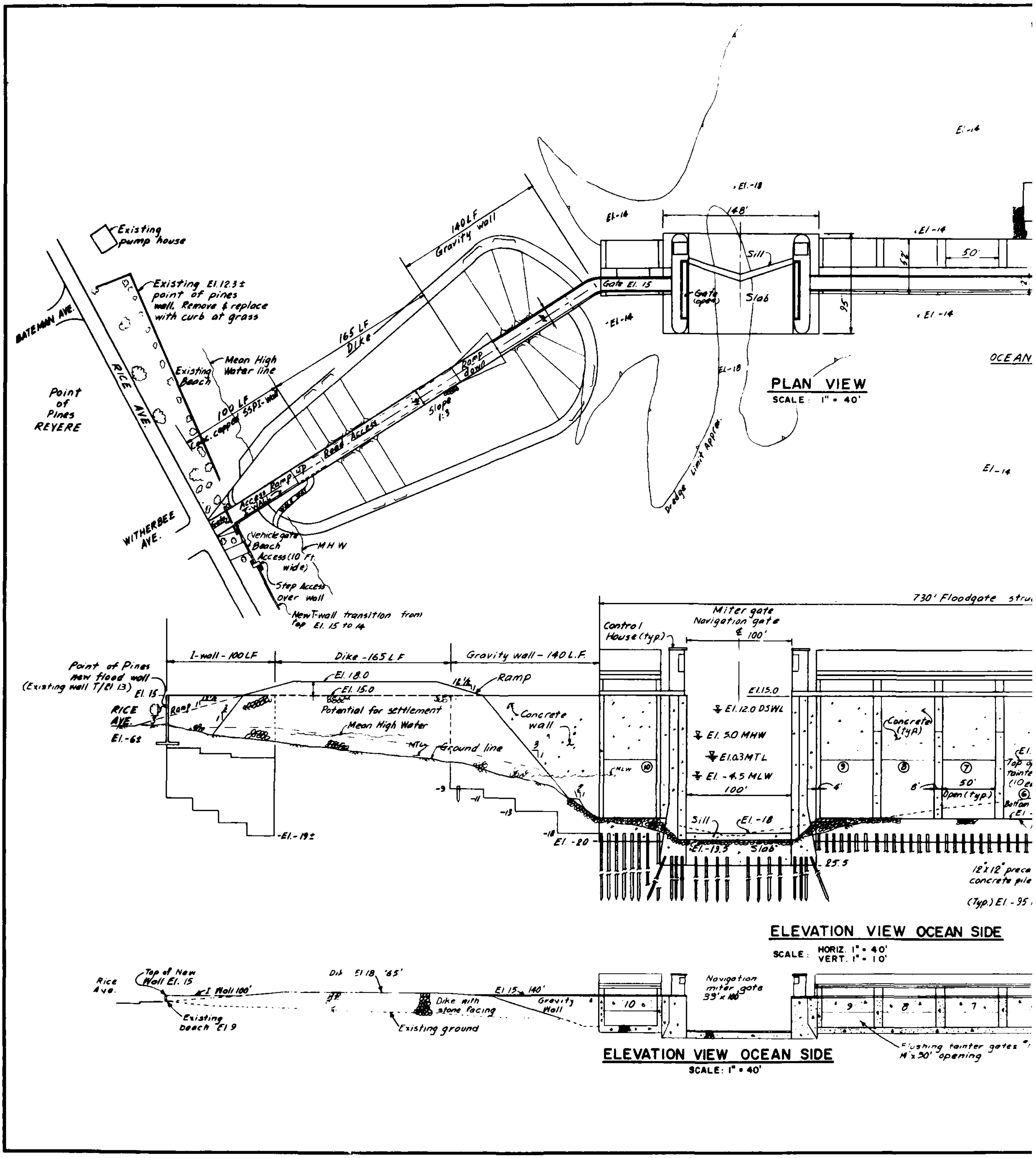
8,900' Dikes, Walls & Tide Gates	Features include 8,900 Feet of Dikes & Walls with Tide Gates
	Earth Dike or Revetment Alignment
	Wall Alignment
Lynn	Feature or Area Protected

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MA

SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

REGIONAL SAUGUS RIVER
FLOODGATE PLAN

OPTION 3


PLAN VIEW
SCALE: 1" = 40'
Existing pump house
Existing El. 12.3± point of pines wall. Remove & replace with curb at grass
BATEMAN AVE.
RICE AVE.
Point of Pines REVERE
WITHERBEE AVE.
Existing Beach
Mean High Water line
100 LF Conc. capped SSPI-wall
165 LF Dike
140 LF Gravity wall
Road Access
Access Ramp up
T-wall
Ramp down
Slope 1:3
Vehicle gate Beach Access (10 Ft. wide)
MHW
Step Access over wall
New T-wall transition from top El. 15 to 14
Gate El. 15
Gate (open)
Sill
Slab
148'
95'
50'
El. -14
El. -18
Dredge Limit Approx.
OCEAN
730' Floodgate structure
Control House (typ)
Miter gate Navigation gate ℄ 100'
I-wall - 100 LF
Dike - 165 L.F.
Gravity wall - 140 L.F.
Point of Pines new flood wall (Existing wall T/El 13)
El. 15
RICE AVE.
El. -6±
Ramp
El. 18.0
El. 15.0
Potential for settlement
Mean High Water
MTL
Ground line
Concrete wall
El. 15.0
El. 12.0 DSWL
El. 5.0 MHW
El. 0.3 MTL
El. -4.5 MLW
100'
MLW
Concrete (typ)
50' Open (typ)
Sill
El. -18
El. -19.5
Slab
El. -20
25.5
-El. -19±
12"x12" precast concrete pile
(Typ.) El. -95
ELEVATION VIEW OCEAN SIDE
SCALE: HORIZ. 1" = 40' VERT. 1" = 10'
Rice Ave.
Top of New Wall El. 15
I Wall 100'
Existing beach El 9
Dike El 18 165'
Dike with stone facing
Existing ground
El 15 140'
Gravity Wall
Navigation miter gate 33'x 100'
Flushing tainter gates 14'x 50' opening
ELEVATION VIEW OCEAN SIDE
SCALE: 1" = 40'

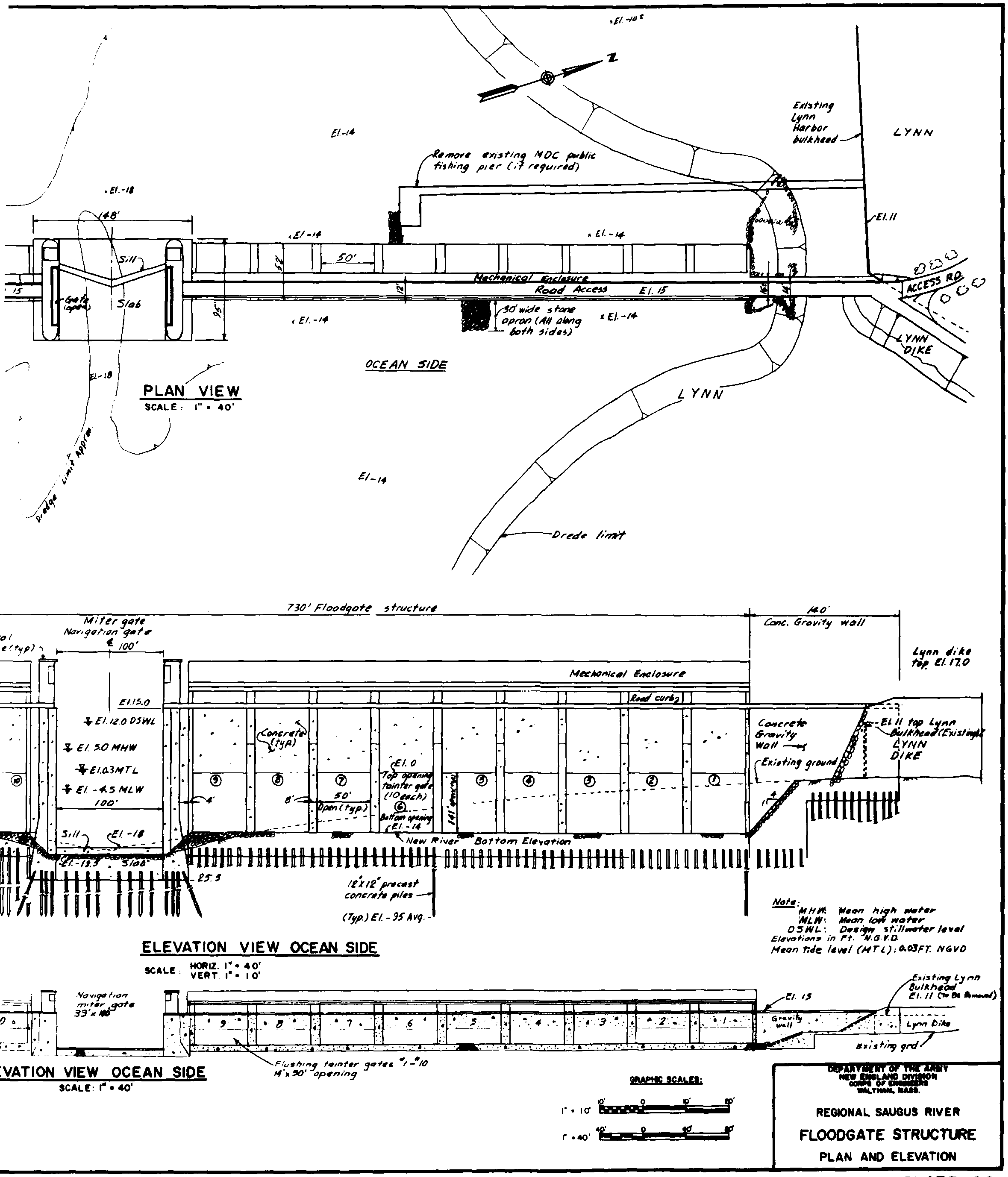
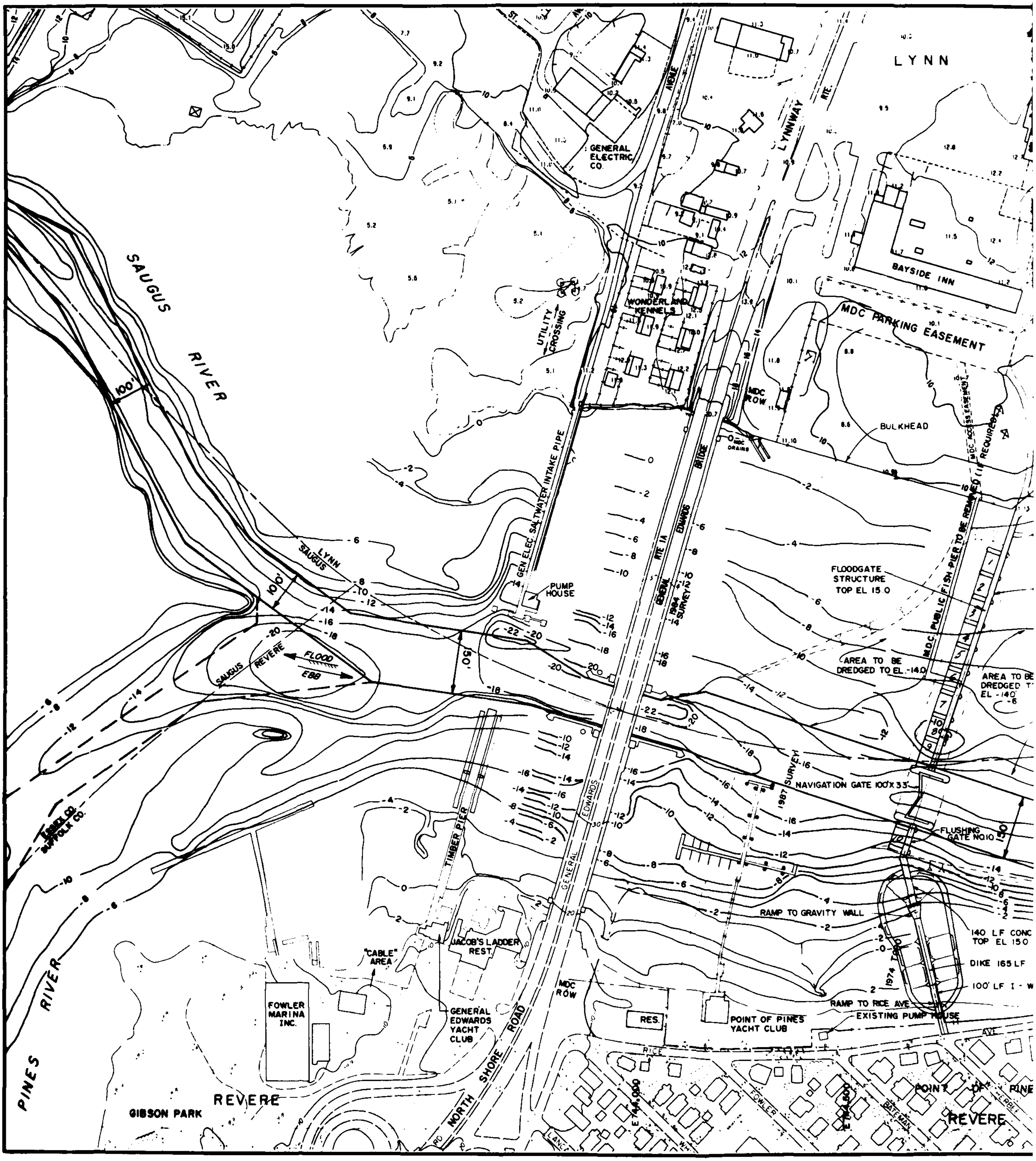

Remove existing MDC public fishing pier (if required)
Existing Lynn Harbor bulkhead
LYNN
El. 11
ACCESS RD.
LYNN DIKE
148'
Sill
Gate (open)
Slab
50'
Mechanical Enclosure
Road Access
El. 15
30' wide stone apron (All along both sides)
OCEAN SIDE
LYNN
PLAN VIEW
SCALE: 1" = 40'
Dredge limit Approx.
Drede limit
El. -14
El. -18
730' Floodgate structure
140'
Conc. Gravity wall
Lynn dike top El. 17.0
Miter gate
Navigation gate
100'
El. 15.0
El. 12.0 DSWL
El. 5.0 MHW
El. 0.3 MTL
El. -4.5 MLW
Concrete (typ)
El. 0
Top opening tainter gate (10 each)
Bottom opening El. -14
50'
Open (typ)
Road curb
Concrete Gravity Wall
Existing ground
El 11 top Lynn Bulkhead (Existing)
LYNN DIKE
New River Bottom Elevation
Sill
El. -18
El. -13.5
Slab
25.5
12"x12" precast concrete piles
(Typ.) El. -95 Avg.
Note:
MHW: Mean high water
MLW: Mean low water
DSWL: Design stillwater level
Elevations in Ft. N.G.V.D.
Mean tide level (MTL): 0.03 FT. NGVD
ELEVATION VIEW OCEAN SIDE
SCALE: HORIZ. 1" = 40' VERT. 1" = 10'
Navigation miter gate 33' x 100'
El. 15
Gravity wall
Existing Lynn Bulkhead El. 11 (To Be Removed)
Lynn Dike
Existing grd
Flushing tainter gates #1-#10 14' x 30' opening
ELEVATION VIEW OCEAN SIDE
SCALE: 1" = 40'
GRAPHIC SCALES:
1" = 10'
1" = 40'
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
REGIONAL SAUGUS RIVER
FLOODGATE STRUCTURE
PLAN AND ELEVATION

PLATE D2


LYNN
GENERAL ELECTRIC CO.
LYNNWAY
AVENUE
SAUGUS RIVER
WONDERLAND KENNELS
UTILITY CROSSING
BAYSIDE INN
MDC PARKING EASEMENT
MDC ROW
MDC DRAINS
BULKHEAD
GEN ELEC SALTWATER INTAKE PIPE
PUMP HOUSE
GENERAL EDWARDS BRIDGE
RTE 1A
1984 SURVEY
FLOODGATE STRUCTURE TOP EL 15.0
MDC PUBLIC FISH PIER TO BE REMOVED
AREA TO BE DREDGED TO EL -14.0
LYNN
SAUGUS
SAUGUS
REVERE
FLOOD
EBB
100'
150'
NAVIGATION GATE 100'X33'
1987 SURVEY
FLUSHING GATE NO10
TIMBER PIER
RAMP TO GRAVITY WALL
140 LF CONC TOP EL 15.0
DIKE 165 LF
1974 TOPO
RAMP TO RICE AVE
EXISTING PUMP HOUSE
POINT OF PINES YACHT CLUB
RES.
MDC ROW
JACOB'S LADDER REST.
"CABLE" AREA
FOWLER MARINA INC.
GENERAL EDWARDS YACHT CLUB
NORTH SHORE ROAD
ESSEX CO
SUFFOLK CO.
PINES RIVER
REVERE
GIBSON PARK
RICE
FOWLER
BATEMAN
REVERE

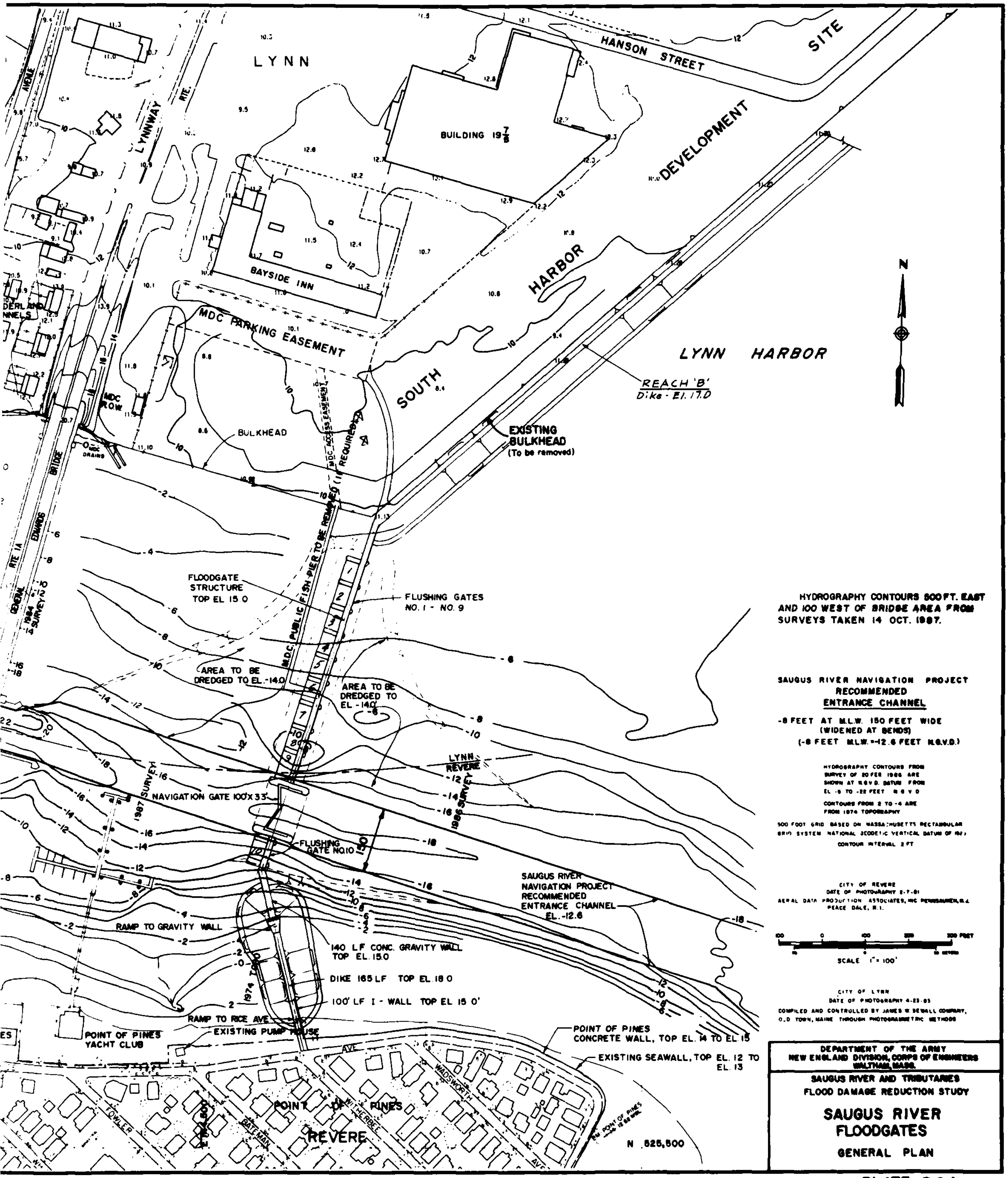
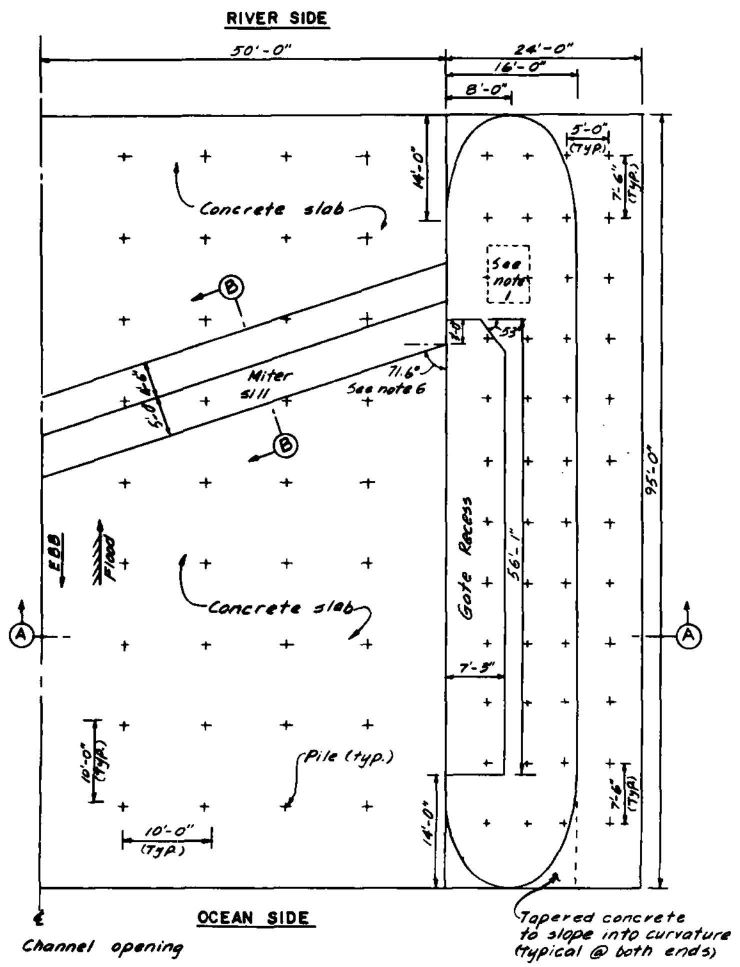
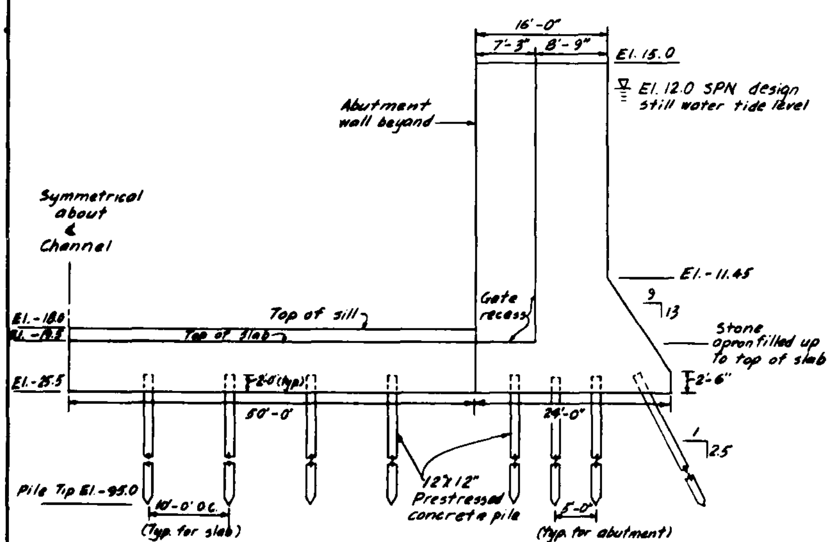

LYNN
HANSON STREET
SITE
DEVELOPMENT
BUILDING 19 7/8
BAYSIDE INN
MDC PARKING EASEMENT
SOUTH HARBOR
LYNN HARBOR
LYNNWAY RTE.
REACH 'B'
Dike - El. 17.0
EXISTING BULKHEAD
(To be removed)
BULKHEAD
MDC ROW
MDC DRAINS
GENERAL EDWARDS BRIDGE RTE 1A
MDC PUBLIC FISH PIER TO BE REMOVED (IF REQUIRED)
MDC ACCESS EASEMENT
FLOODGATE STRUCTURE TOP EL 15.0
FLUSHING GATES NO. 1 - NO. 9
AREA TO BE DREDGED TO EL.-14.0
AREA TO BE DREDGED TO EL -14.0
LYNN
REVERE
1984 SURVEY
1986 SURVEY
1987 SURVEY
1974 TOPO
NAVIGATION GATE 100'X 33'
FLUSHING GATE NO.10
150
SAUGUS RIVER NAVIGATION PROJECT RECOMMENDED ENTRANCE CHANNEL EL. -12.6
RAMP TO GRAVITY WALL
140 LF CONC. GRAVITY WALL TOP EL. 15.0
DIKE 165 LF TOP EL. 18.0
100' LF I - WALL TOP EL 15.0'
RAMP TO RICE AVE
EXISTING PUMP HOUSE
POINT OF PINES YACHT CLUB
POINT OF PINES CONCRETE WALL, TOP EL. 14 TO EL. 15
EXISTING SEAWALL, TOP EL. 12 TO EL. 13
POINT OF PINES
REVERE
FOWLER
BATEMAN
WITHERBEE
WADSWORTH
AVE
N 525,500
HYDROGRAPHY CONTOURS 500 FT. EAST AND 100 WEST OF BRIDGE AREA FROM SURVEYS TAKEN 14 OCT. 1987.
SAUGUS RIVER NAVIGATION PROJECT
RECOMMENDED
ENTRANCE CHANNEL
-8 FEET AT M.L.W. 150 FEET WIDE
(WIDENED AT BENDS)
(-8 FEET M.L.W. = -12.6 FEET N.G.V.D.)
CONTOUR INTERVAL 2 FT
SCALE 1" = 100'
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY
SAUGUS RIVER
FLOODGATES
GENERAL PLAN

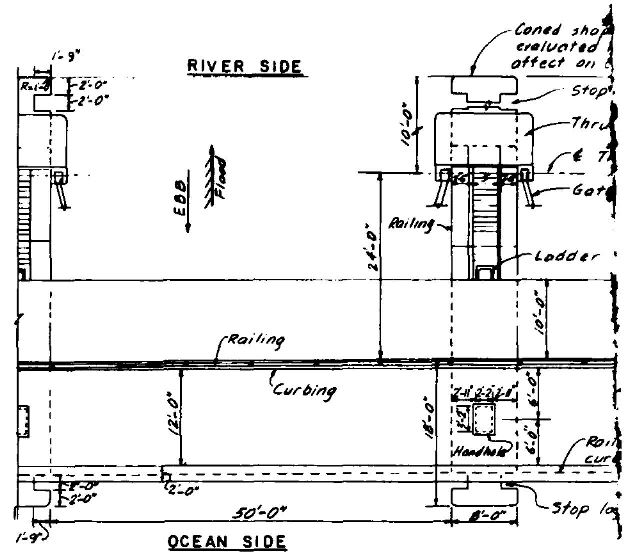
PLATE D2A



PLAN - MITER GATE STRUCTURE
SCALE: 1/8" = 1'-0"

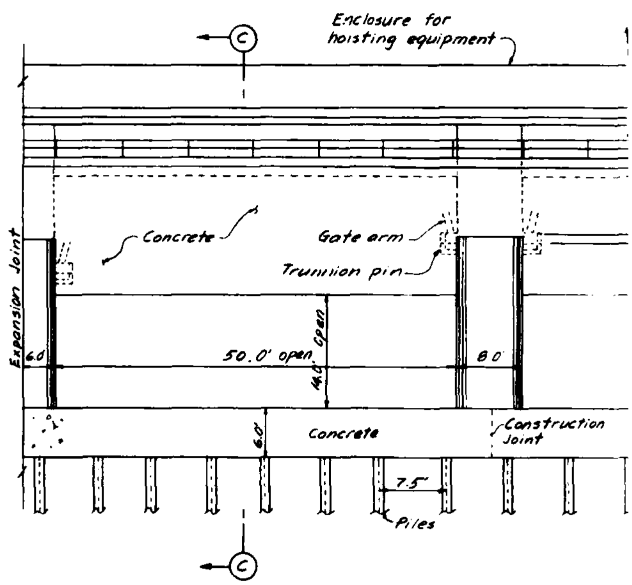


SECTION A - A
SCALE: 1/8" = 1'-0"



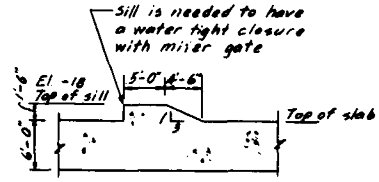
PLAN - TAINTER GATE STRUCTURE (TYPICA

SCALE: 1/8" = 1'-0"

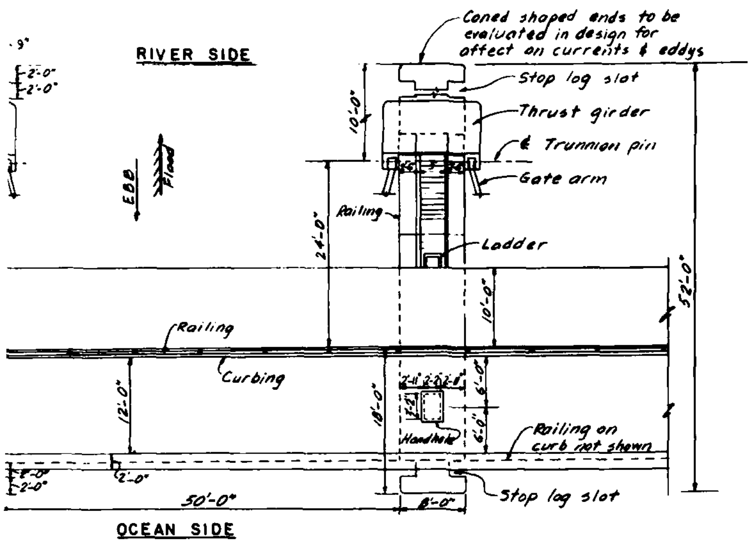


ELEVATION - TAINTER GATE STRUCTURE (T

SCALE: 1/8" = 1'-0"



SECTION B - B
SCALE: 1/8" = 1'-0"

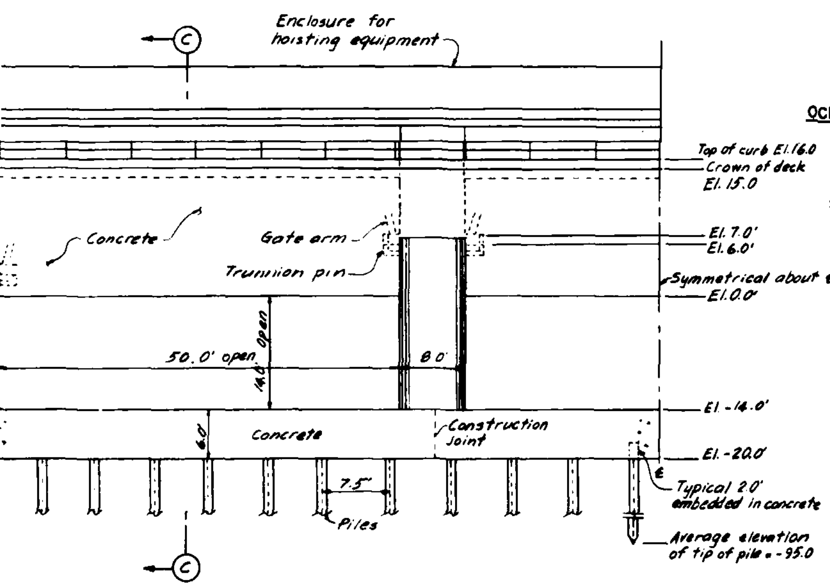


PLAN - TAINTER GATE STRUCTURE (TYPICAL)

SCALE: 1/8" = 1'-0"

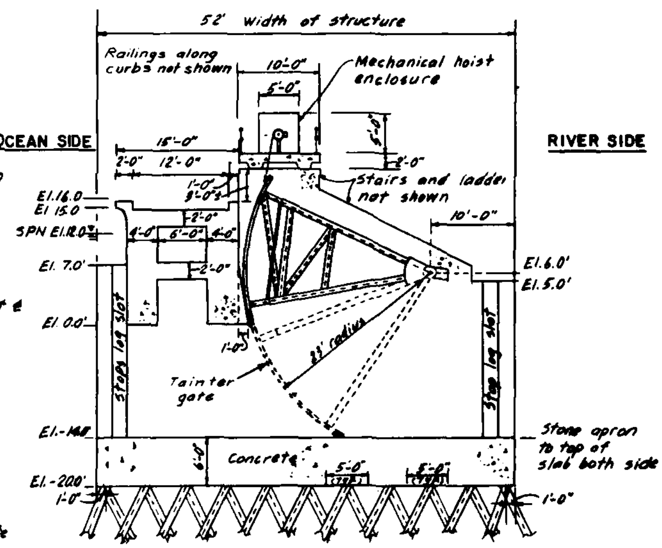
NOTES: (MITER GATE)

1. A Cavity will be provided to house miter gate machinery. The recess may be disregarded as it is assumed the weight of the material therein is equal to the weight of the concrete.
2. Slab piles are located 10'-0" x 10'-0" O.C.
3. Abutment piles are located 5'-0" x 7'-6" O.C.
4. Slab and sill are considered fully reinforced with steel
5. The miter gate abutment is considered fully reinforced with steel.
6. Angle will vary depending on gate connection details. Angle is roughly 1:3. Further investigation into gate design is required for exact angle.



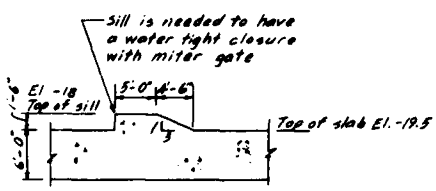
ELEVATION - TAINTER GATE STRUCTURE (TYPICAL)

SCALE: 1/8" = 1'-0"



SECTION C - C

SCALE: 1/8" = 1'-0"



SECTION B - B

SCALE: 1/8" = 1'-0"

GRAPHIC SCALES

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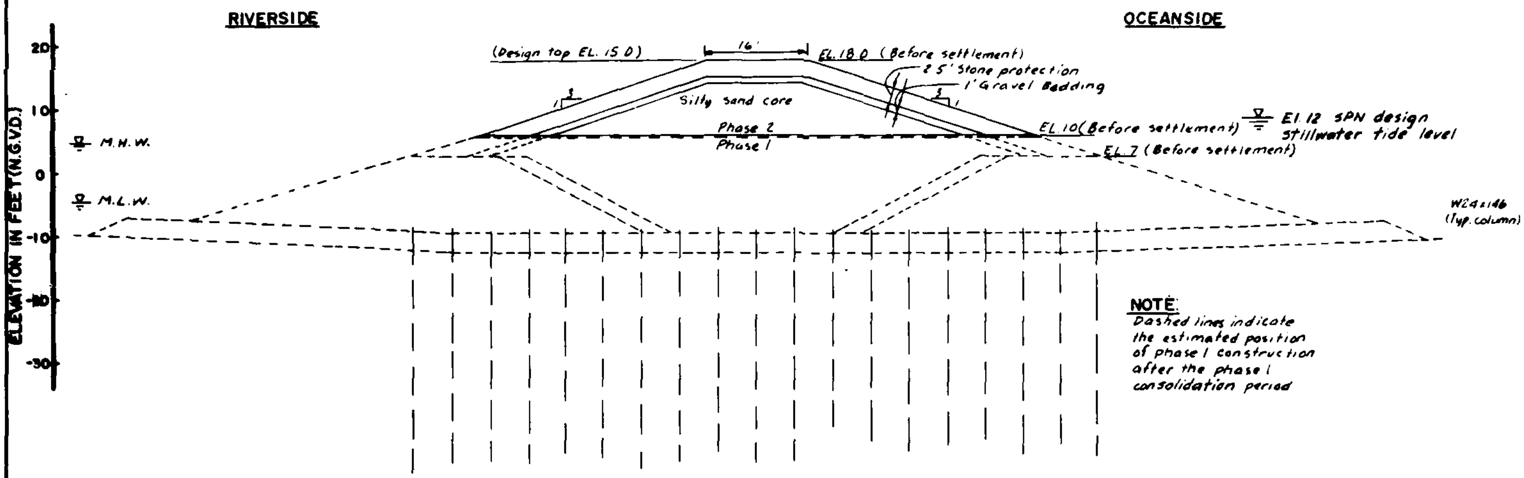
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

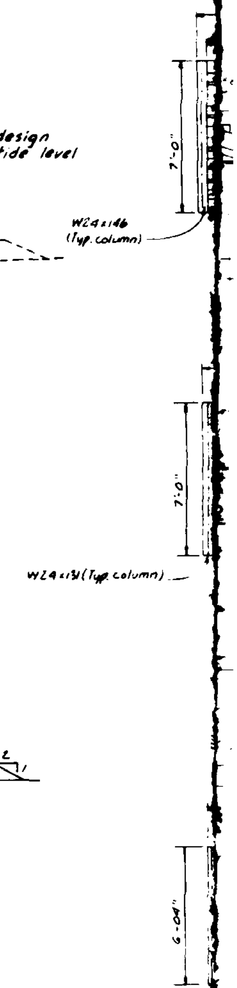
REGIONAL SAUGUS RIVER
FLOODGATE STRUCTURE
MISCELLANEOUS DETAILS NO. 1

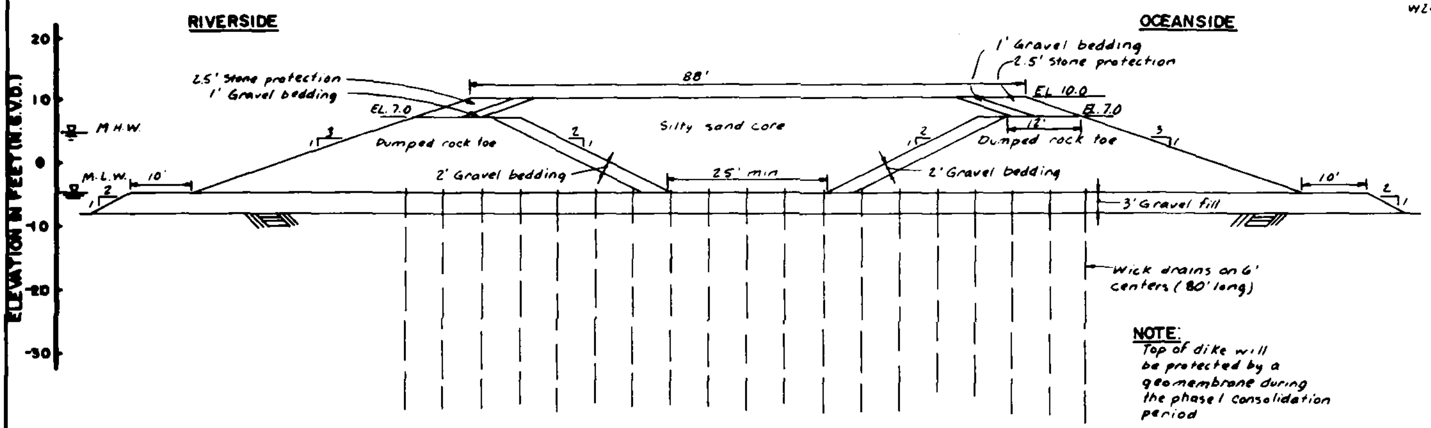
PLATE D3



TYPICAL DIKE SECTION-PHASE 2

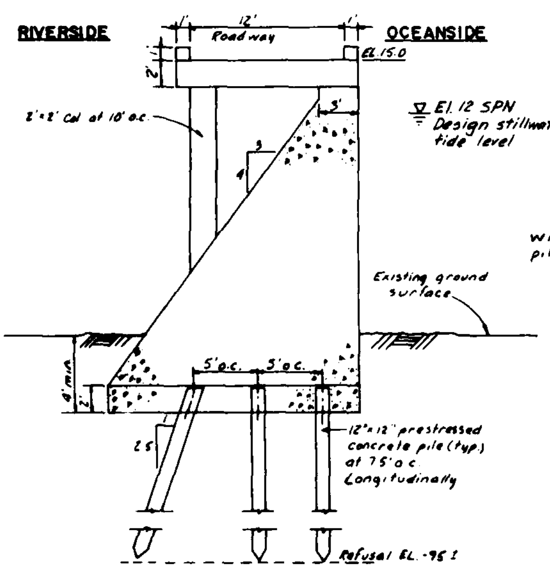
SCALE: 1" = 10'





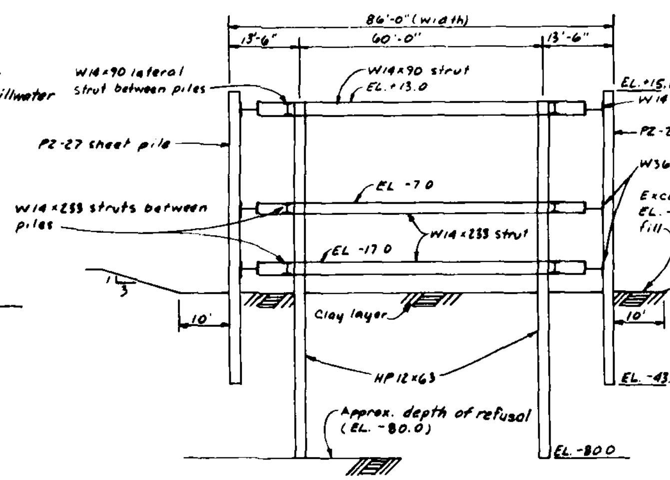
TYPICAL DIKE SECTION-PHASE 1

SCALE: 1" = 10'



TYPICAL SECTION-GRAVITY WALL

SCALE: 1" = 5'

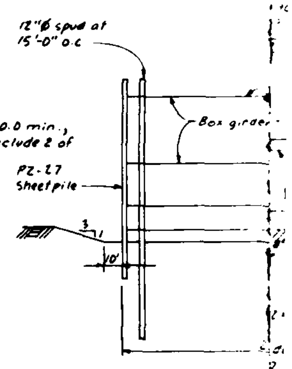


TYPICAL SECTION - BRACED COFFERDAM

FOR TAINTER GATES

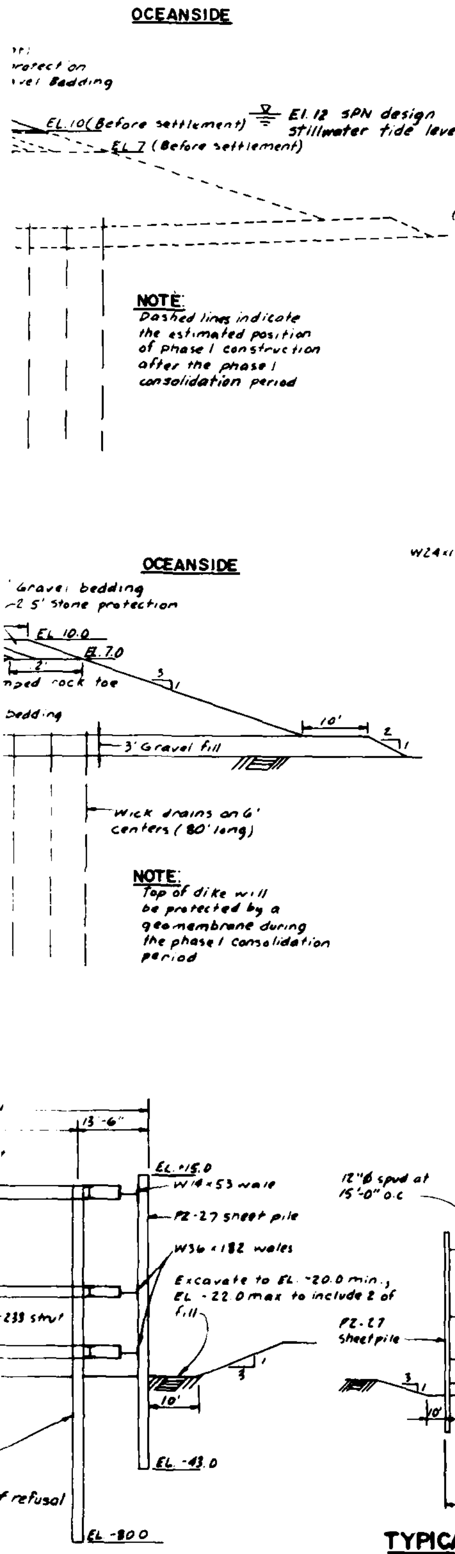
N.T.S.

NOTE: Strut spacing is 29'-0" o.c. per length of coffer dam.



TYPICAL SECTION-

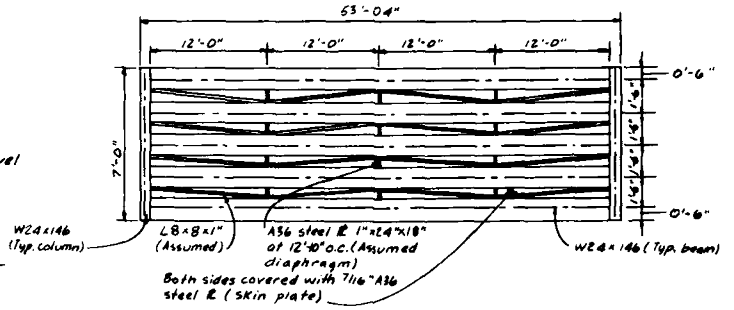
FOR M



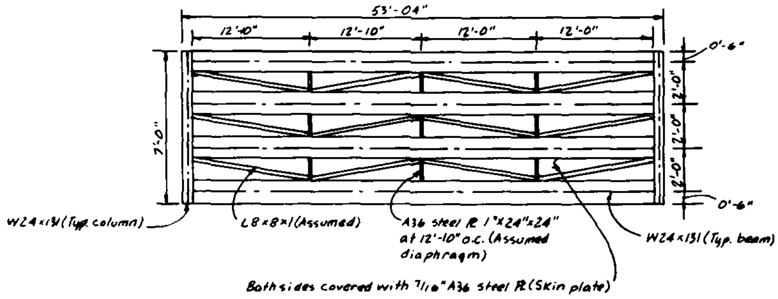
CED COFFERDAM

GATES

ength of coffer dam.



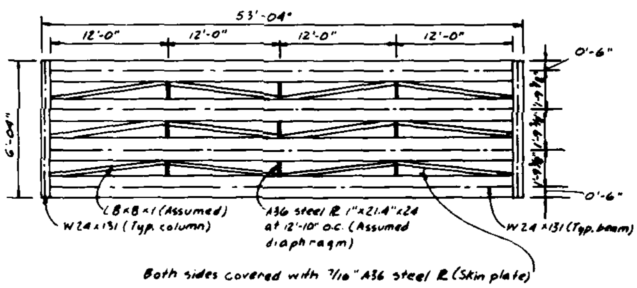
ELEVATION-TAINTER GATE 1



ELEVATION-TAINTER GATE 2&3

OCEANSIDE-STOP STRUCTURE

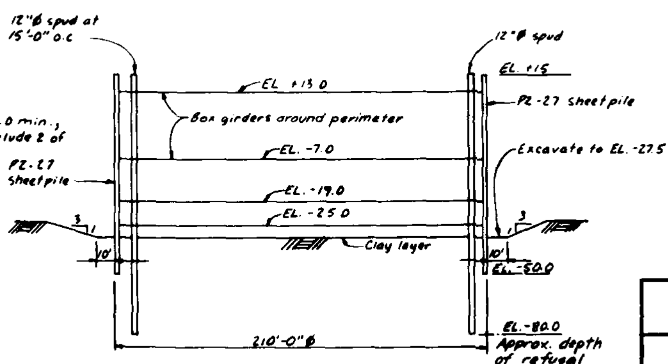
N. T. S.



ELEVATION-TAINTER GATES 1, 2 AND 3

RIVERSIDE - STOP STRUCTURE

N. T. S.

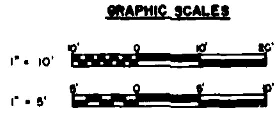


TYPICAL SECTION-RING WALL COFFERDAM

FOR MITER GATE

N. T. S.

GRAPHIC SCALES



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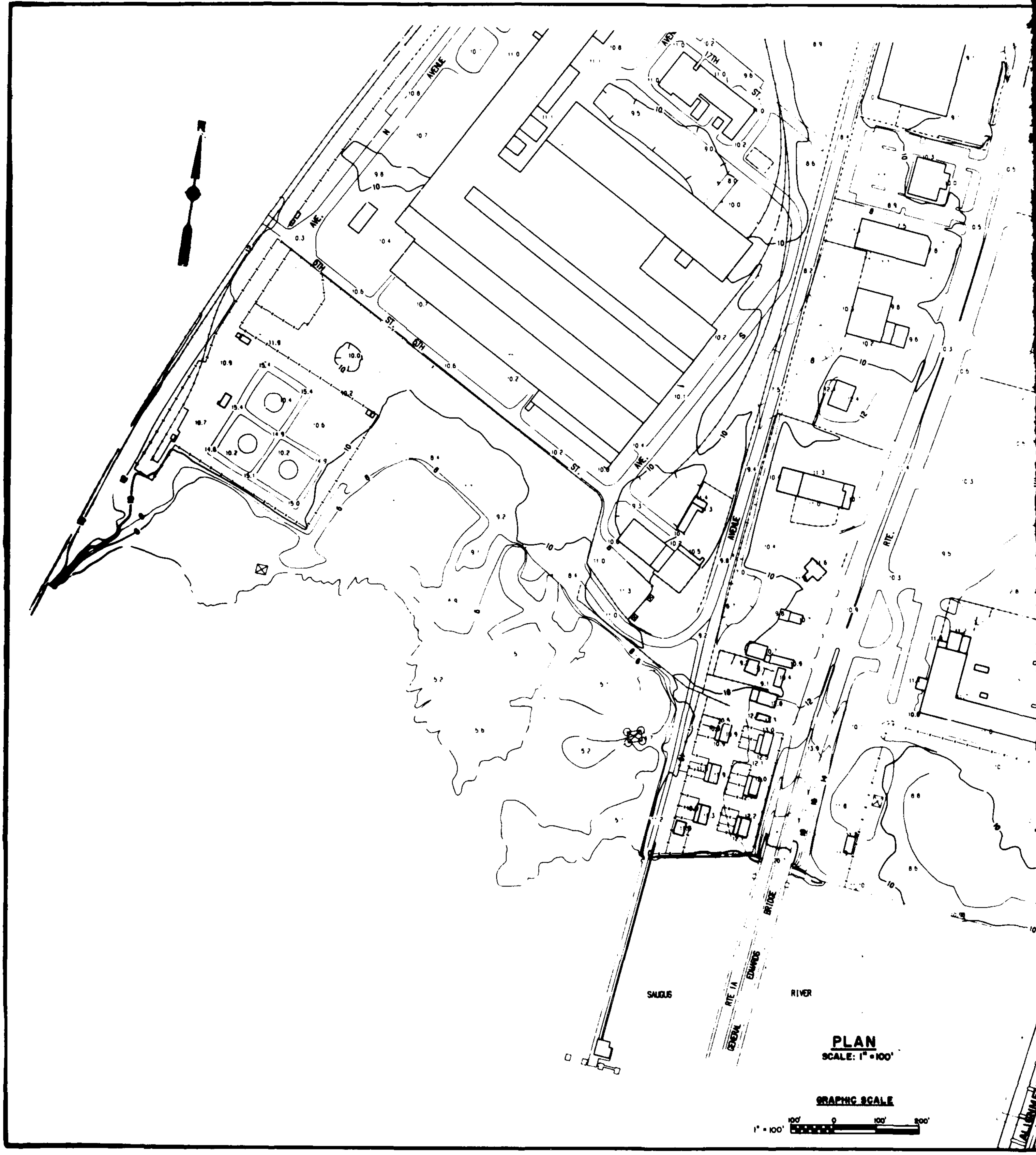
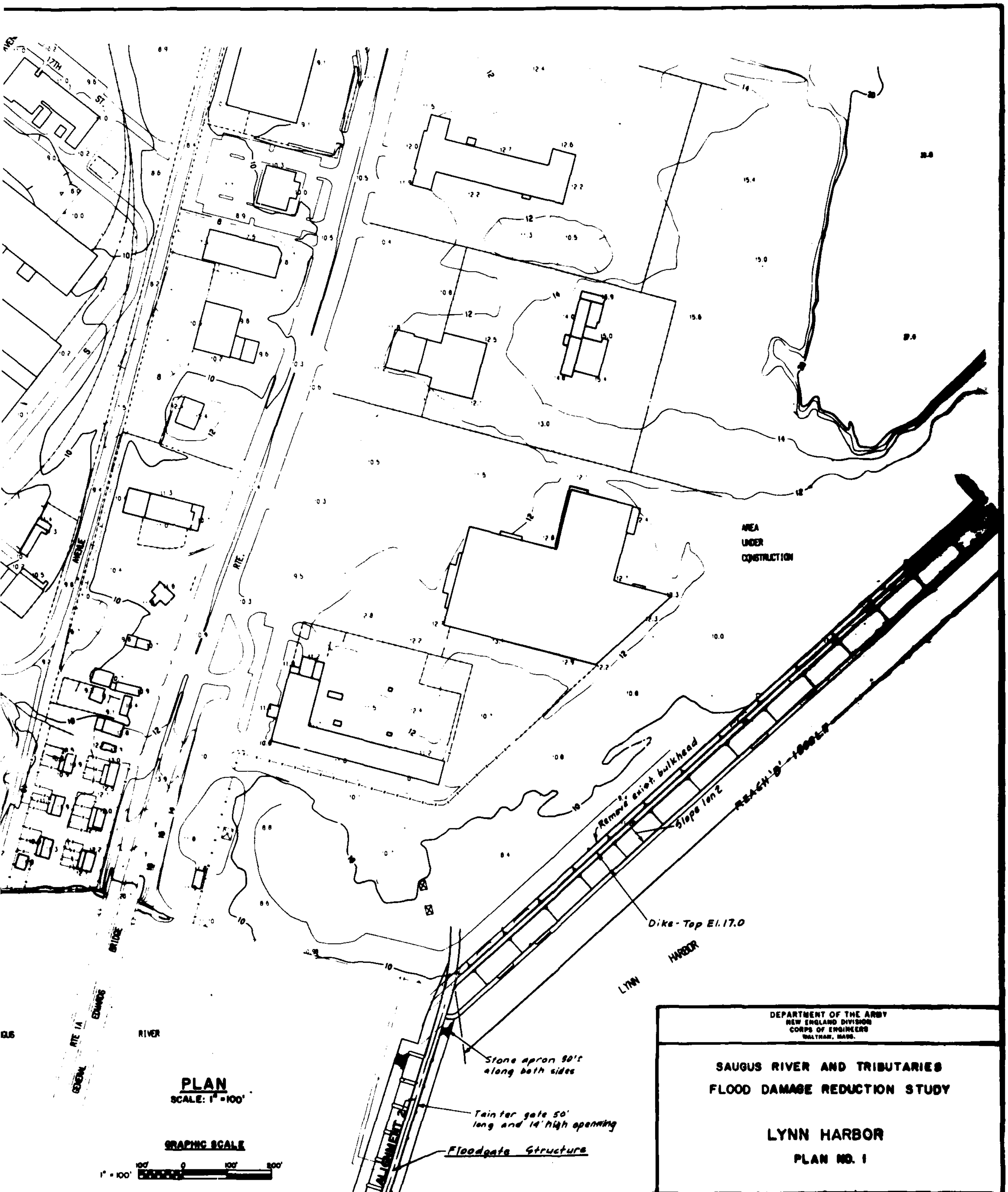
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

REGIONAL SAUGUS RIVER
FLOODGATE STRUCTURE
MISCELLANEOUS DETAILS NO. 2

PLATE D4



N
N AVENUE
AVE.
8TH ST.
8TH ST.
17TH ST.
AVENUE
S AVE.
AVENUE
RTE.
SAUGUS
RIVER
RTE 1A
GENERAL EDWARDS BRIDGE
PLAN
SCALE: 1" = 100'
GRAPHIC SCALE
1" = 100'
100'
0
100'
200'



AREA UNDER CONSTRUCTION
Remove exist. bulkhead
Slope 1 on 2
REACH 'B' 1000 L.F.
Dike-Top El. 17.0
LYNN HARBOR
RIVER
RTE 1A
GENERAL EDWARDS BRIDGE
Stone apron 30'± along both sides
Tainter gate 50' long and 14' high opening
Floodgate Structure
ALIGNMENT 2
PLAN
SCALE: 1" = 100'
GRAPHIC SCALE
1" = 100'
100' 0 100' 200'
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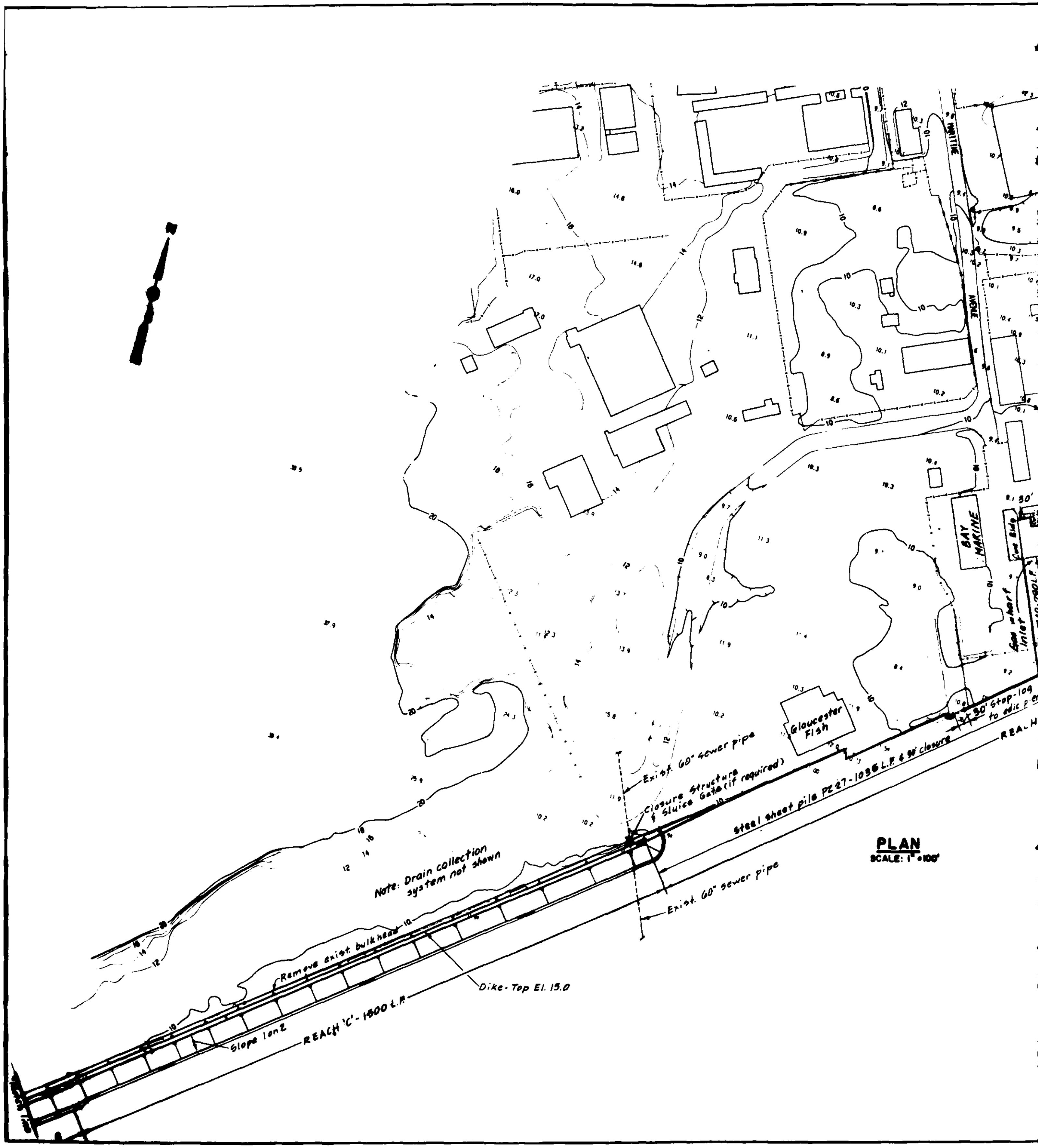
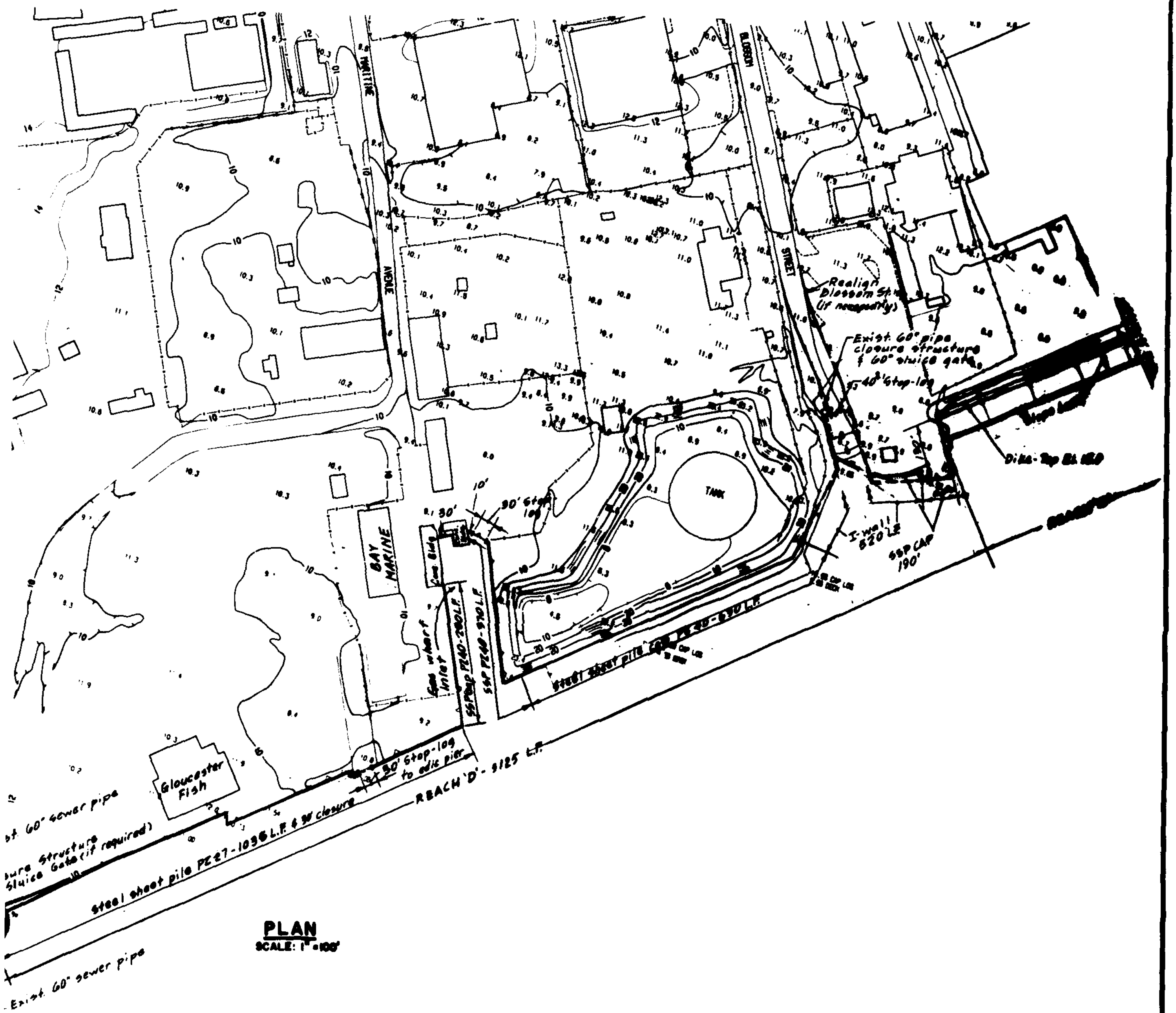
WALTHAM, MASS.
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY
LYNN HARBOR
PLAN NO. 1



BAY MARINE
Gloucester Fish
Gas wharf inlet
Exist. 60" sewer pipe
Closure Structure & Sluice Gate (if required)
Steel sheet pile PZ 27-1036 L.F. & 30' closure
30' Stop-log
Note: Drain collection system not shown
Remove exist. bulkhead
Dike-Top El. 15.0
Slope 1 on 2
REACH 'C'-1500 L.F.
PLAN
SCALE: 1" = 100'



PLAN
SCALE: 1" = 100'

GRAPHIC SCALE
1" = 100' 100' 0 100' 200'

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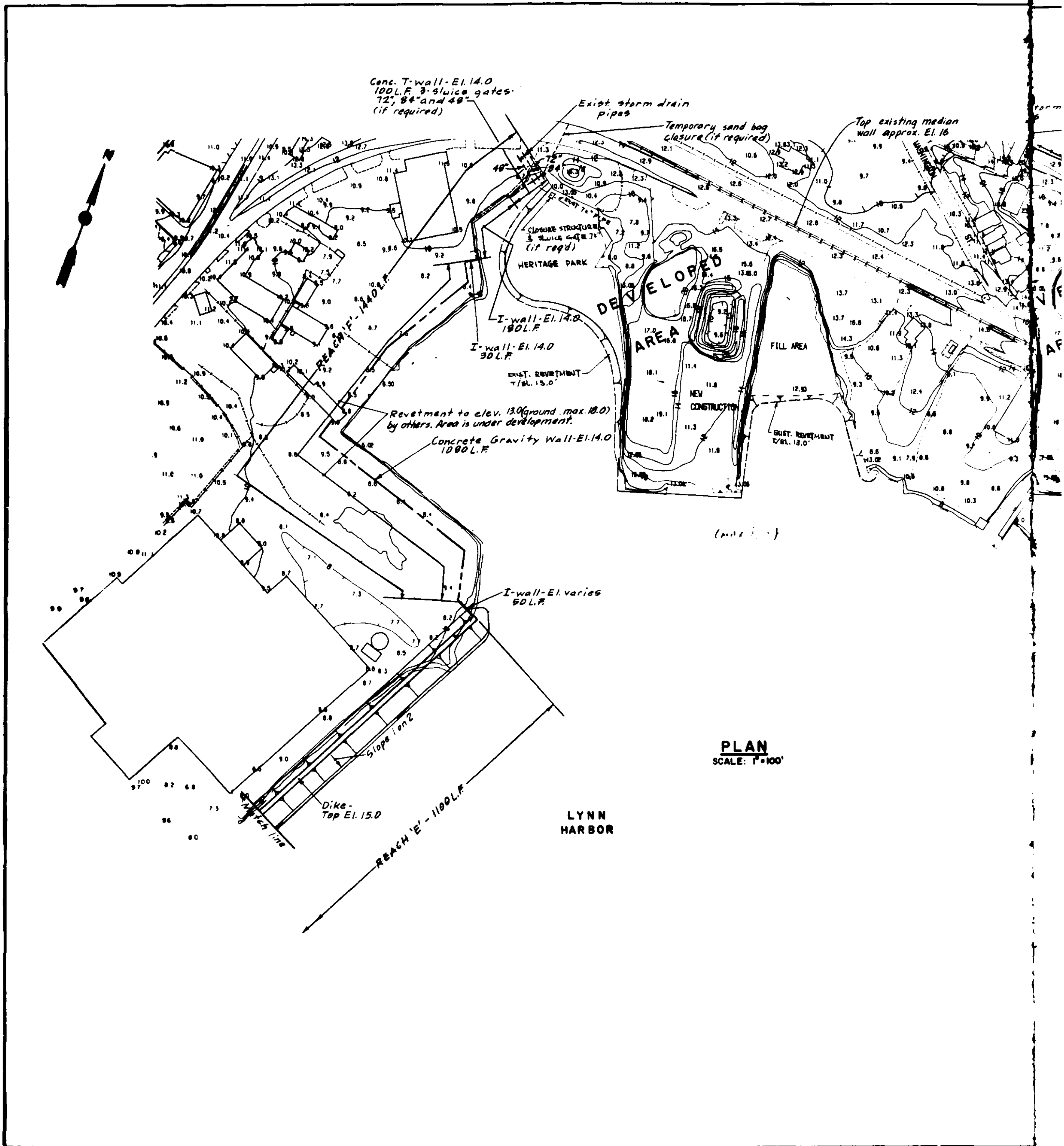
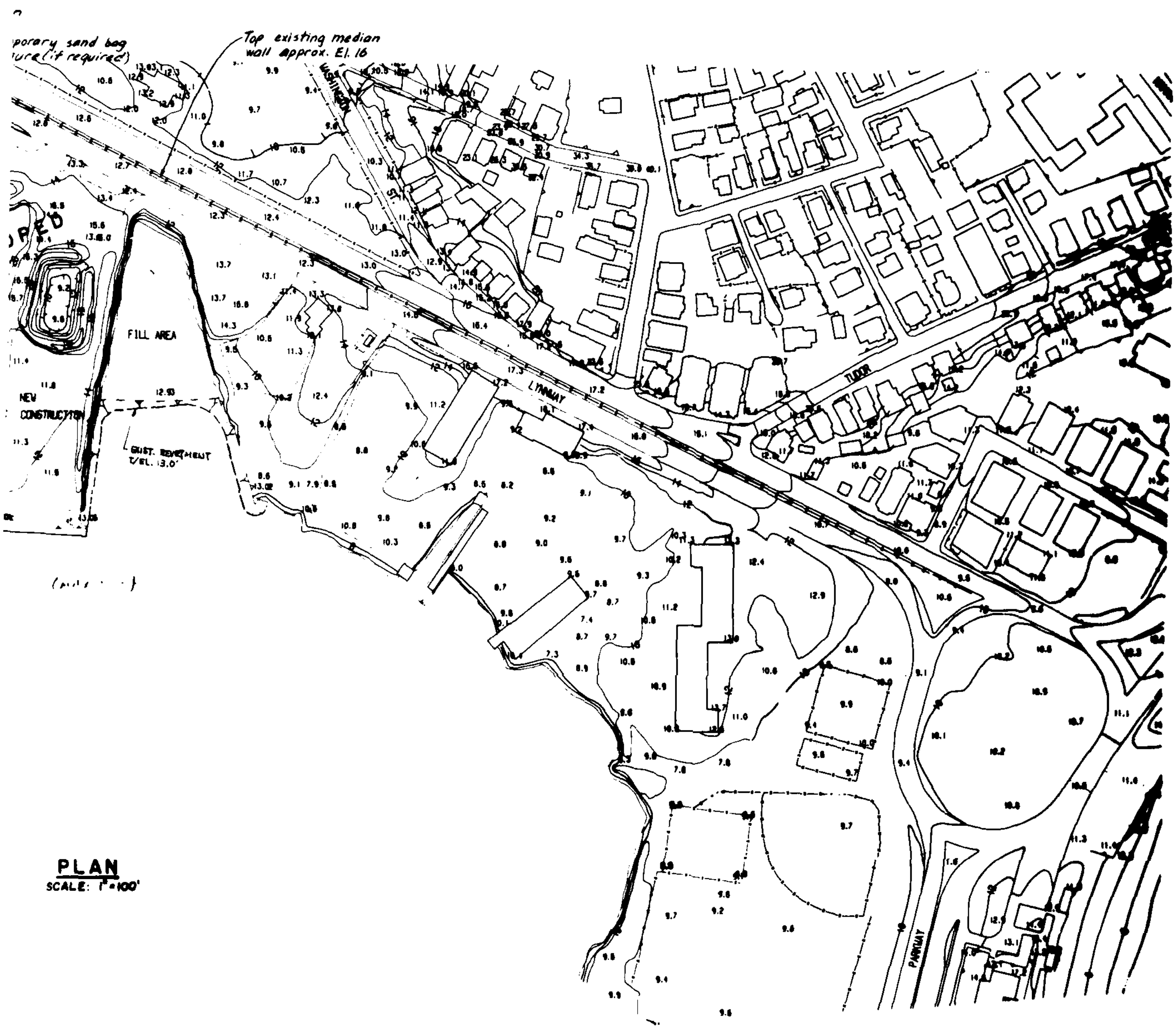
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

LYNN HARBOR
PLAN NO. 2



Conc. T-wall - El. 14.0
100 L.F. 3-sluice gates-
72", 84" and 48"
(if required)
Exist. storm drain
pipes
Temporary sand bag
closure (if required)
Top existing median
wall approx. El. 16
CLOSURE STRUCTURE
& SLUICE GATE 72"
(if req'd)
HERITAGE PARK
DEVELOPED AREA
FILL AREA
NEW CONSTRUCTION
I-wall - El. 14.0
190 L.F.
I-wall - El. 14.0
30 L.F.
EXIST. REVETMENT
T/EL. 13.0'
Revetment to elev. 13.0 (ground . max. 18.0)
by others. Area is under development.
Concrete Gravity Wall - El. 14.0
1080 L.F.
REACH 'F' - 1440 L.F.
I-wall - El. varies
50 L.F.
Slope 1 on 2
Dike -
Top El. 15.0
Match line
REACH 'E' - 1100 L.F.
PLAN
SCALE: 1"=100'
LYNN
HARBOR



PLAN
SCALE: 1" = 100'

GRAPHIC SCALE
1" = 100' 100' 0 100' 200'

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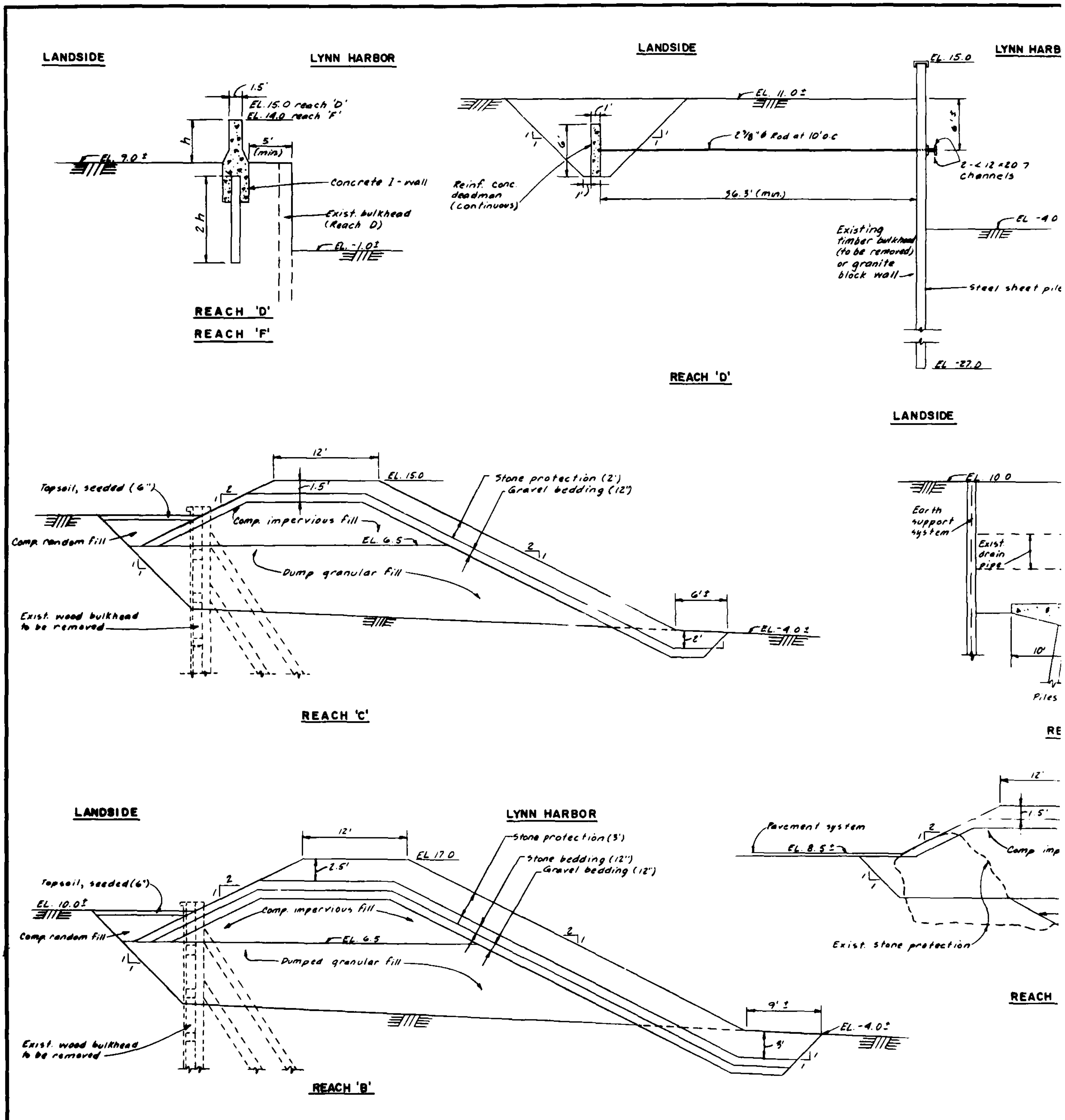
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

LYNN HARBOR

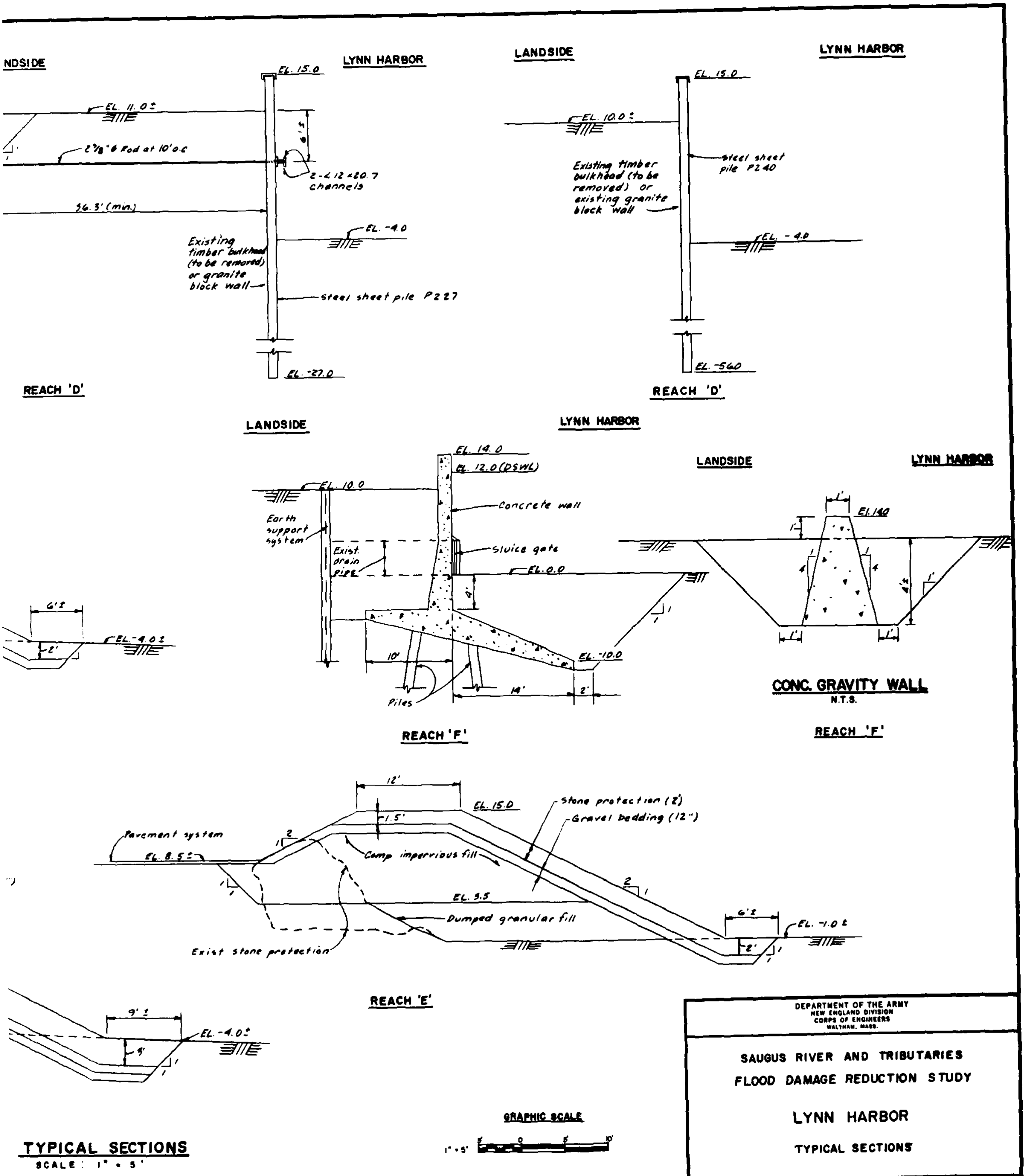
PLAN NO. 3

PLATE D7



TYPICAL SECTIONS

SCALE: 1" = 5'



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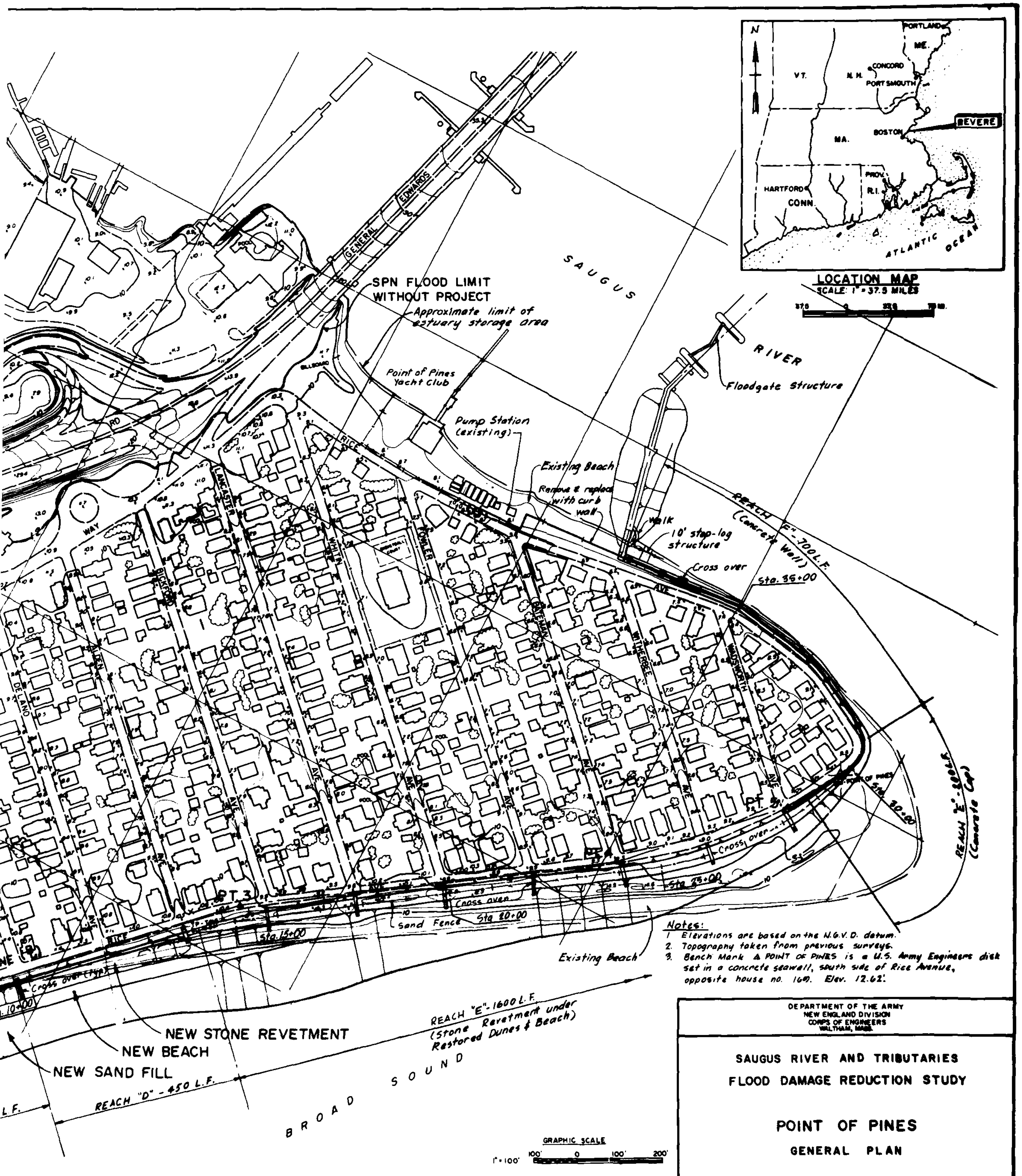
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

LYNN HARBOR

TYPICAL SECTIONS

PLATE D8


Approximate limit of estuary storage area
PINES RIVER
N
PARKING AREA
TENNIS COURT
BOAT YARD
THAYER AVE
RIVER AVE
NORTH SHORE RD
GENERAL
LYNN WAY
HARRINGTON
PINES RD
GOODWIN AVE
CHAMBERLAIN AVE
DELANO AVE
BICKFORD AVE
LANCASTER AVE
RICE AVE
CAREY CIRCLE
BASE LINE
PT 1
PT 2
PT 3
Sta. 0+00
Sta. 5+00
Sta. 10+00
Sta. 15+00
El. 6.0
Cross over
Cross over (Typ.)
NEW STONE REVETMENT
NEW BEACH
NEW SAND FILL
REACH "A"
REACH "B"-440L.F.
REACH "C"- 430 L.F.
REACH "D" - 450 L.F.
Fill to meet exist. grade
BROAD



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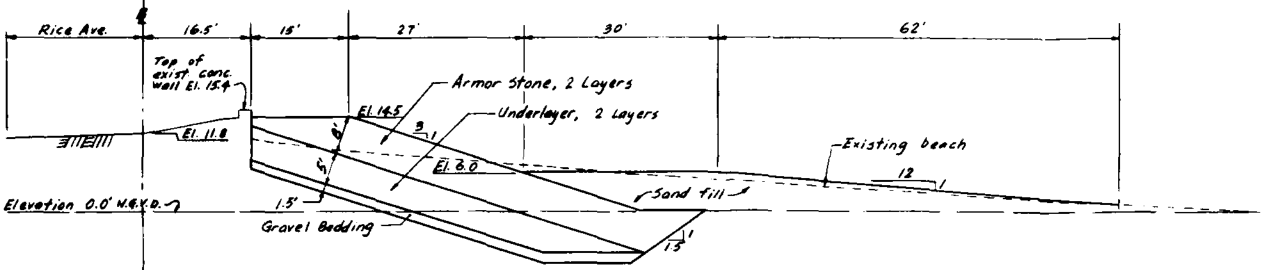
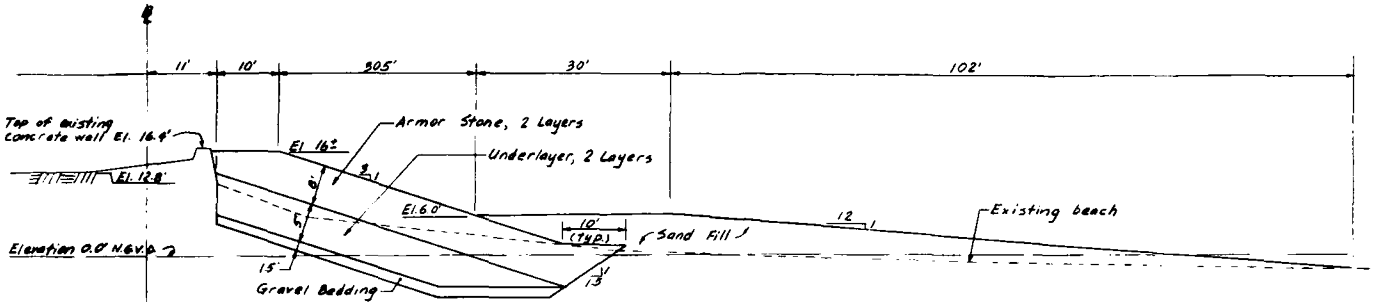
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

POINT OF PINES
GENERAL PLAN

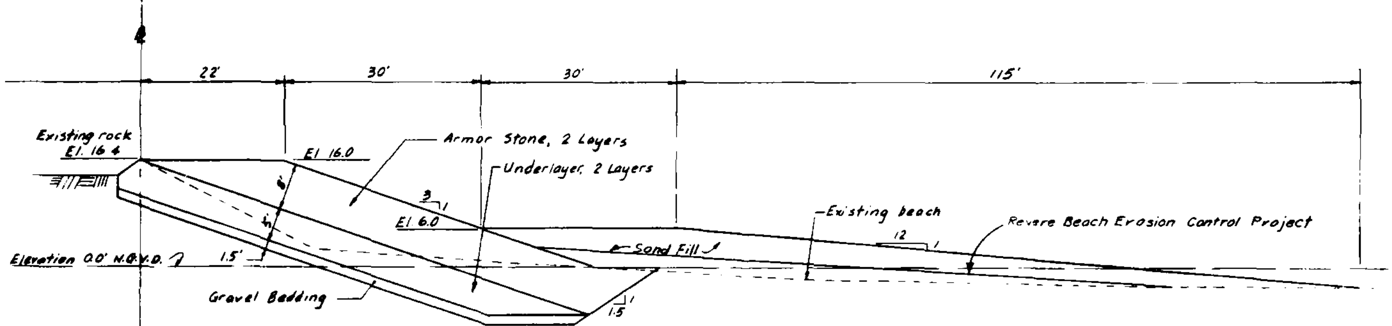
PLATE D9

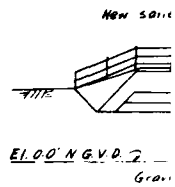


REACH "D"

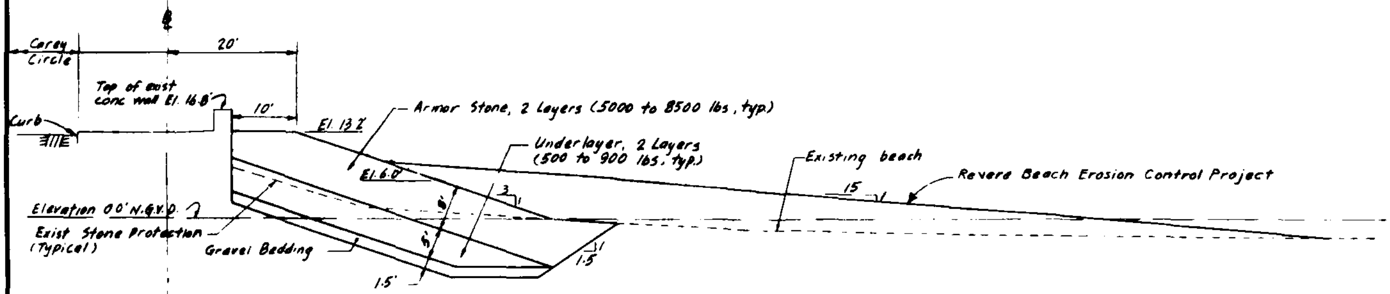


REACH "C"





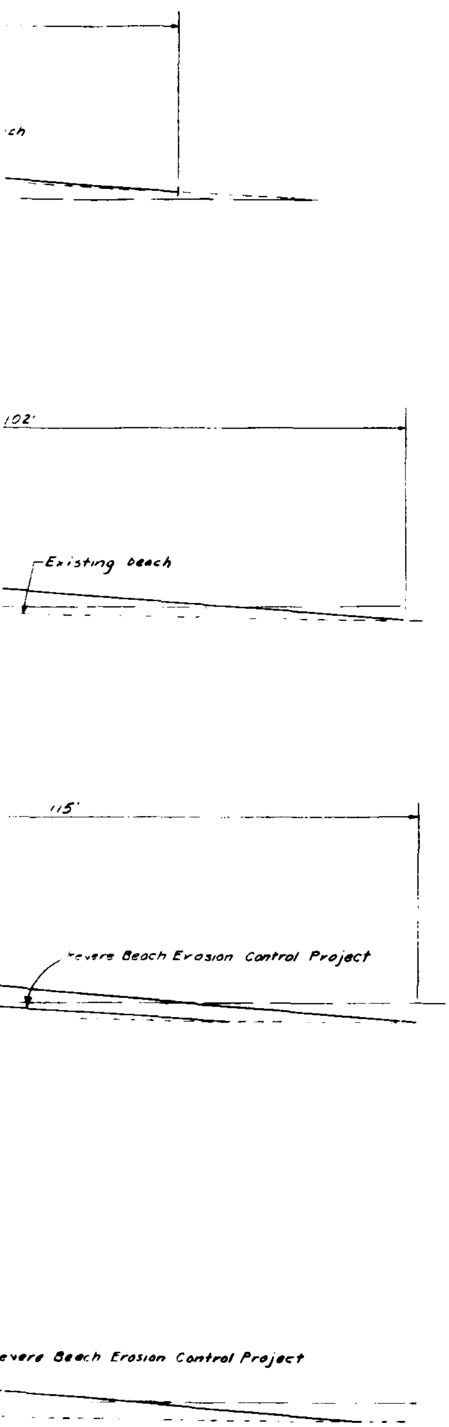
REACH "B"

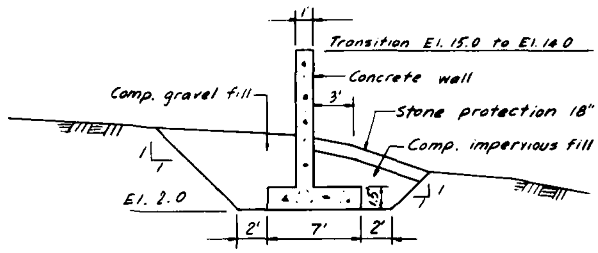


REACH "A"

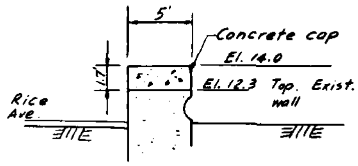
TYPICAL SECTIONS

SCALE 1" = 10'

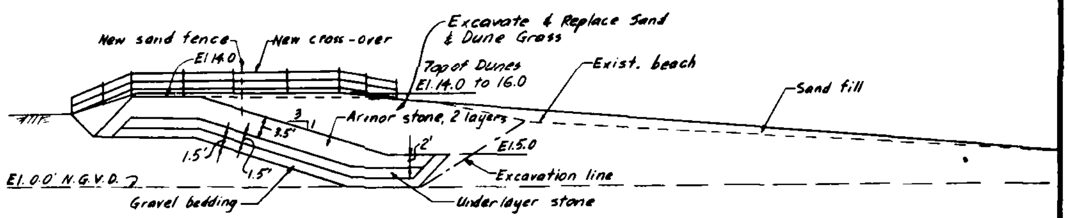




REACH "F"
(CONCRECTE WALL)
SCALE: 1" = 5'



REACH "E"
(CONCRETE CAP)
SCALE: 1" = 5'



REACH "E"
(STONE REVETMENT & DUNE RESTORATION)

NOTE:
Elevations are based on the N.G.V.D. datum.

TYPICAL SECTIONS
SCALE 1" = 10'

GRAPHIC SCALES
1" = 10': 10' 0 10' 20'
1" = 5': 5' 0 5' 10'

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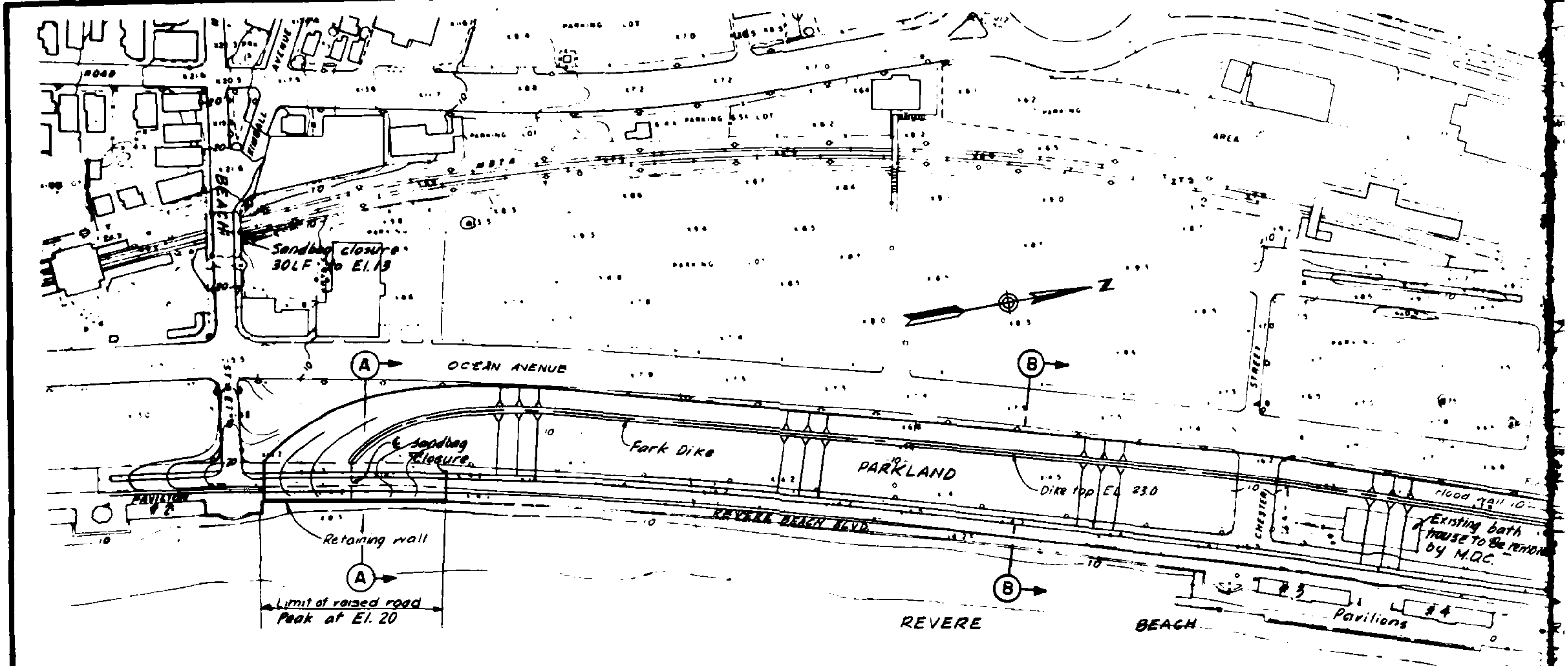
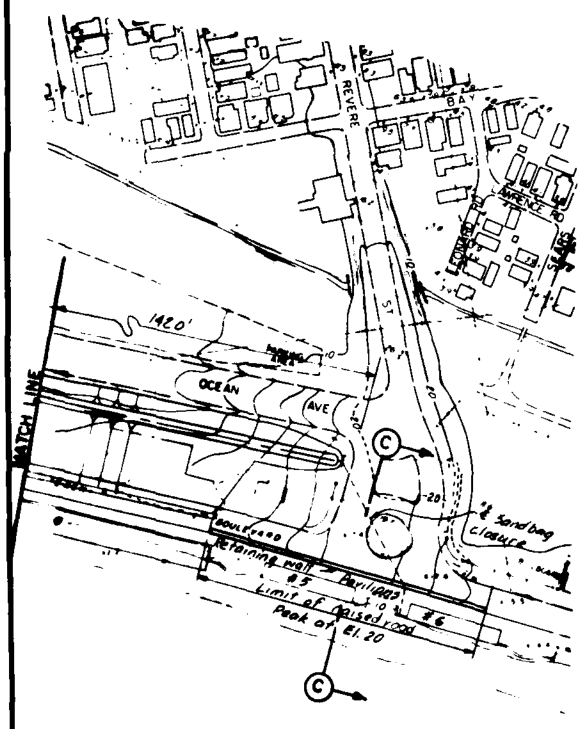
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

POINT OF PINES
TYPICAL SECTIONS

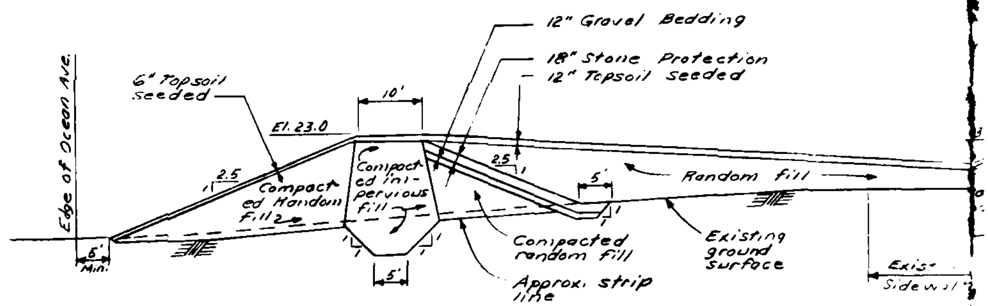
PLATE D10



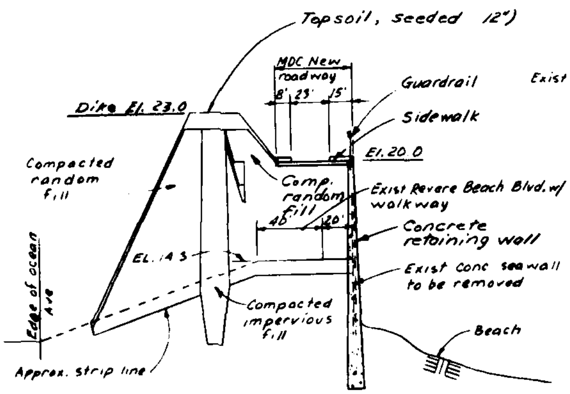
PLAN
SCALE: 1"=100'



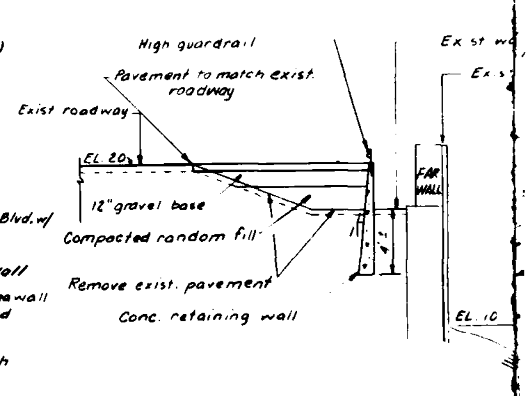
PLAN (CONT'D)
SCALE: 1"=100'



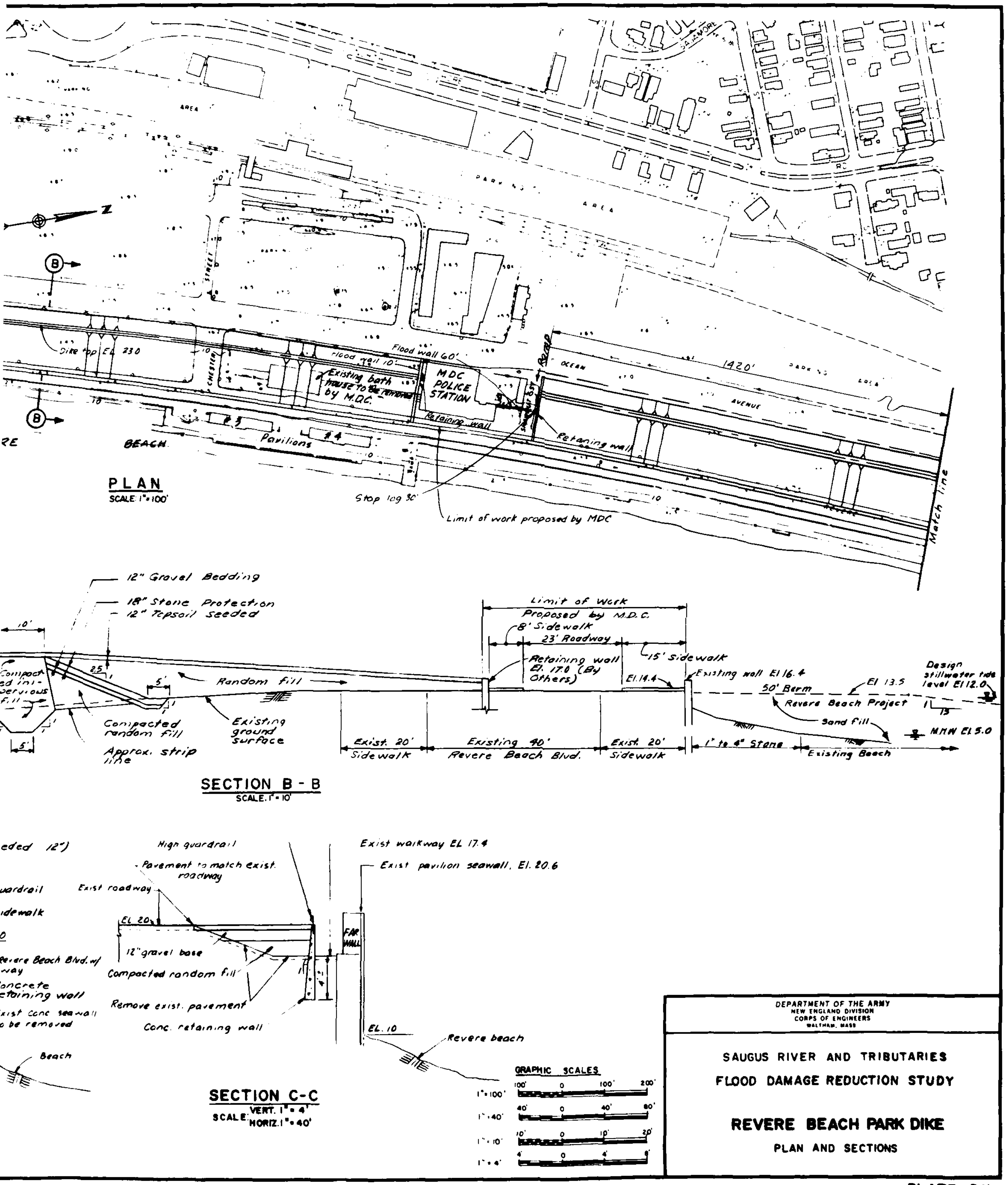
SECTION B - B
SCALE: 1"=10'



SECTION A-A
SCALE: HORIZ. 1"=40' VERT. 1"=4'



SECTION C-C
SCALE: VERT. 1"=4' HORIZ. 1"=40'



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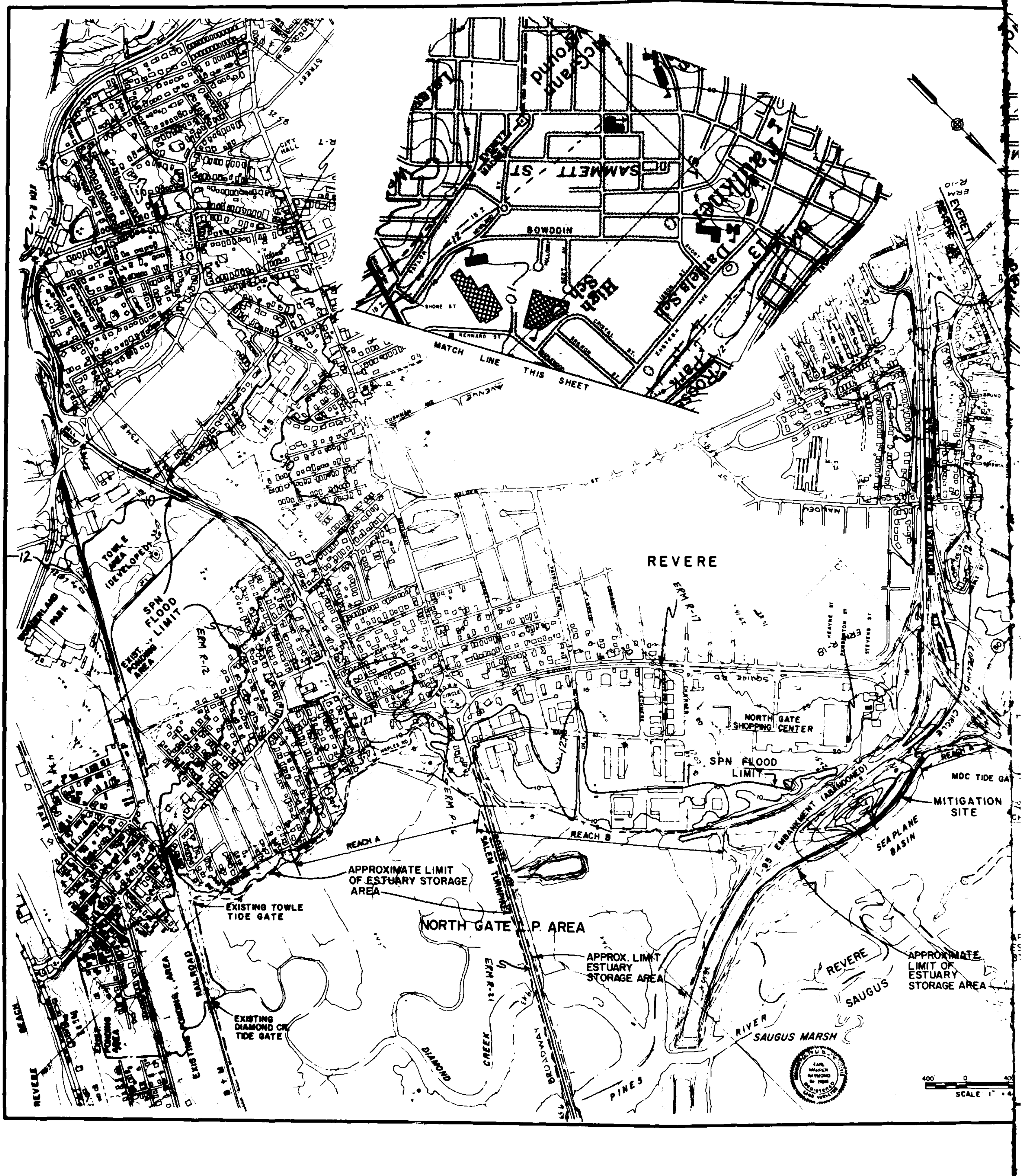
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

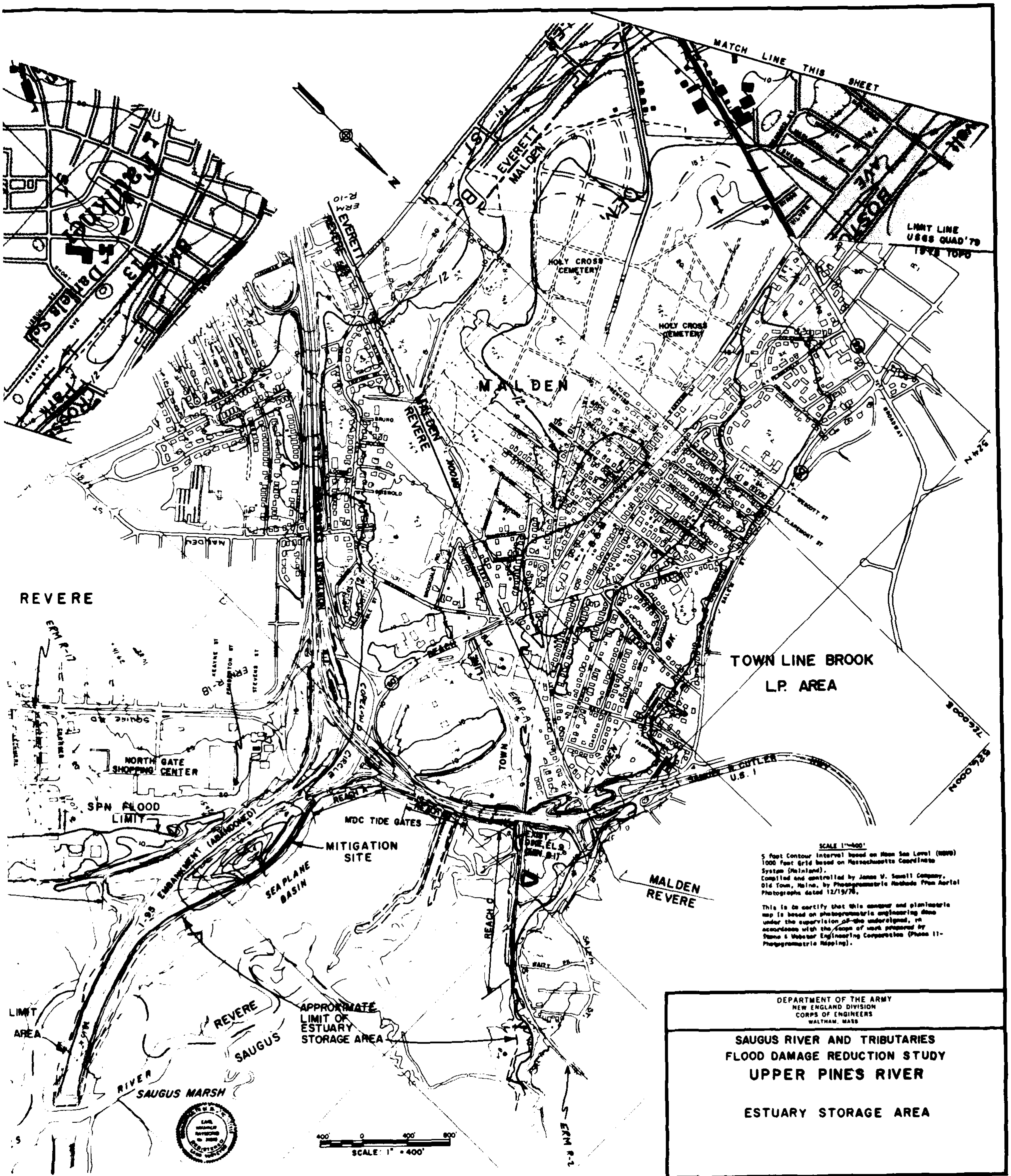
REVERE BEACH PARK DIKE

PLAN AND SECTIONS

PLATE D11



REVERE
MATCH LINE THIS SHEET
SAMMETT ST
BOWDOIN
CITY HALL
TOWLE AREA (DEVELOPED)
SPN FLOOD LIMIT
EXIST. PONDING AREA
ERM R-12
ERM R-17
ERM R-18
ERM R-21
ERM R-10
WONDERLAND PARK
NORTH GATE SHOPPING CENTER
SPN FLOOD LIMIT
MDC TIDE GA
MITIGATION SITE
SEAPLANE BASIN
I-95 EMBANKMENT (ABANDONED)
REACH A
REACH B
APPROXIMATE LIMIT OF ESTUARY STORAGE AREA
EXISTING TOWLE TIDE GATE
NORTH GATE P. AREA
APPROX. LIMIT ESTUARY STORAGE AREA
APPROXIMATE LIMIT OF ESTUARY STORAGE AREA
REVERE
SAUGUS
SAUGUS RIVER
SAUGUS MARSH
EXISTING DIAMOND CR. TIDE GATE
DIAMOND CREEK
BROADWAY
SALEM TURNPIKE
PINES
RAILROAD
REVERE BEACH
EVERETT
MALDEN
SQUIRE RD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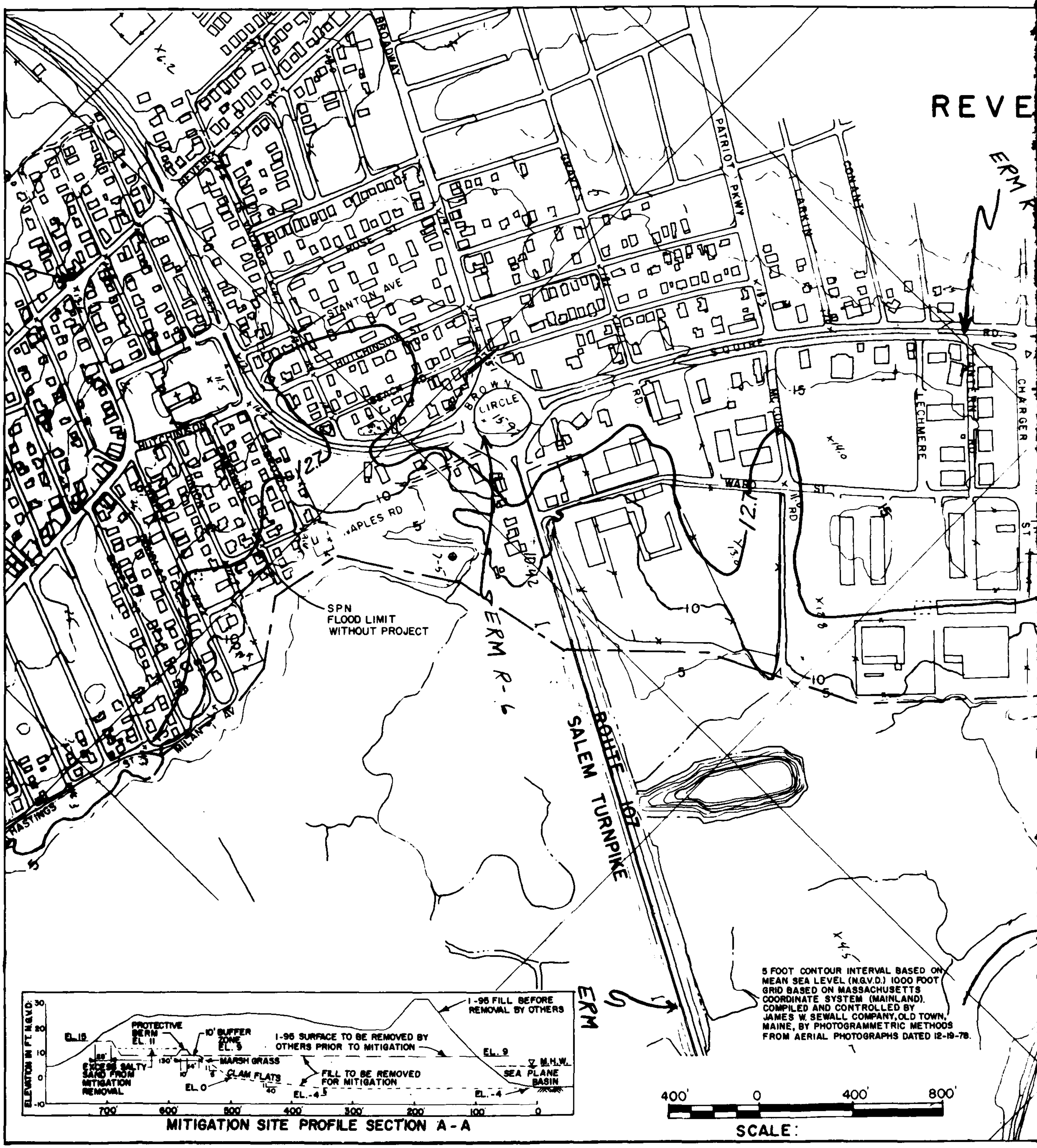
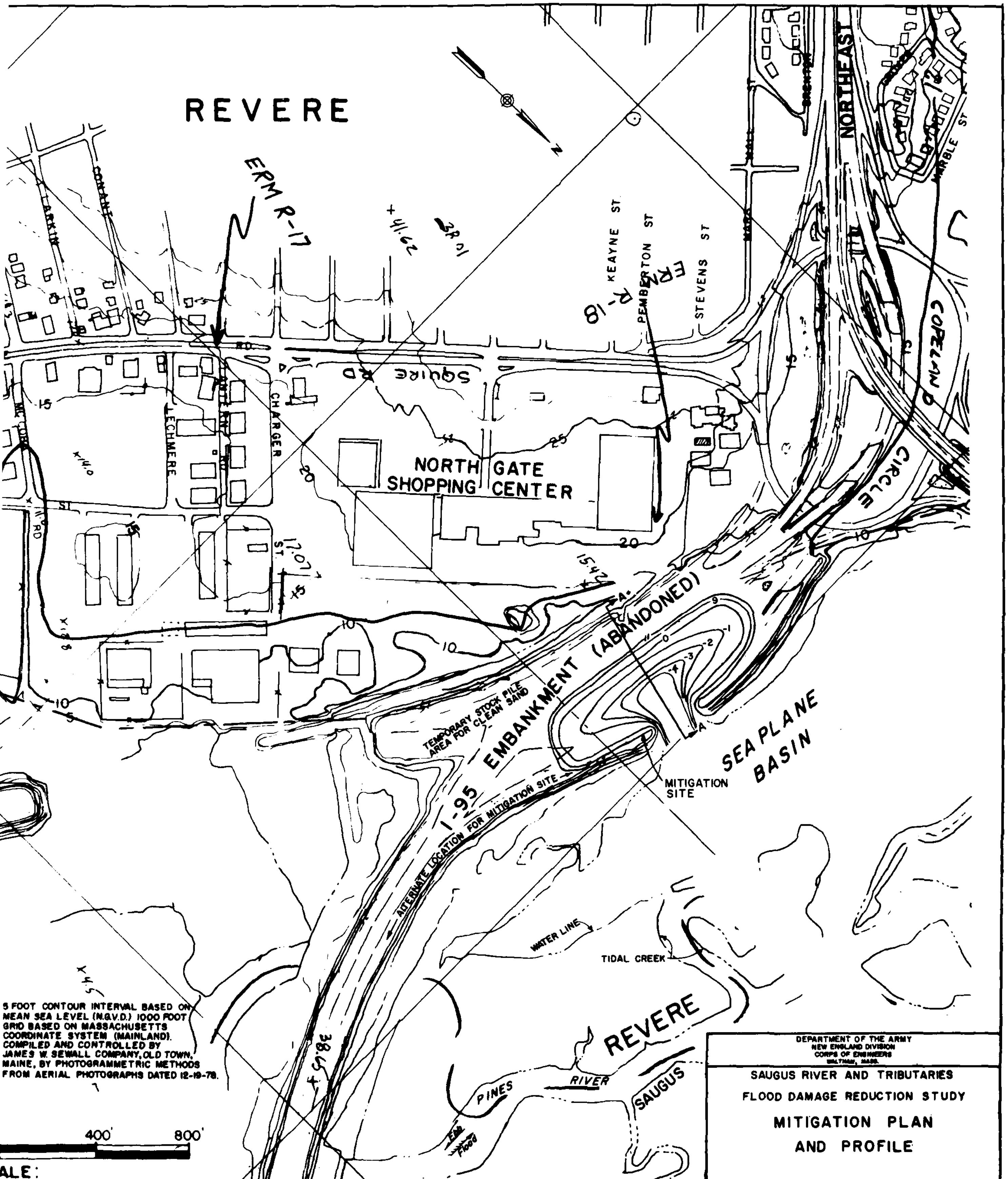
WALTHAM, MASS
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY
UPPER PINES RIVER
ESTUARY STORAGE AREA
MATCH LINE THIS SHEET
LIMIT LINE
USGS QUAD '79
1978 TOPO
EVERETT
MALDEN
REVERE
HOLY CROSS CEMETERY
TOWN LINE BROOK
L.P. AREA
NORTH GATE SHOPPING CENTER
SPN FLOOD LIMIT
MITIGATION SITE
MDC TIDE GATES
SEAPLANE BASIN
MALDEN
REVERE
APPROXIMATE LIMIT OF ESTUARY STORAGE AREA
REVERE
SAUGUS
RIVER
SAUGUS MARSH
ERM R-17
ERM R-18
ERM R-10
ERM R-1
ERM R-2
U.S. 1
SCALE: 1" = 400'

PLATE D12



REVE
BROADWAY
PATRIOT PKWY
LARKIN
CONANT
REVERE
ROSE ST
STANTON AVE
HUTCHINSON
BEACH
BROWN CIRCLE
SQUIRE RD.
LECHMERE
CHARGER ST
WARD ST
NAPLES RD
HASTINGS ST
MILAN AV
SPN
FLOOD LIMIT
WITHOUT PROJECT
ERM R-6
ERM R
ERM
12.7
ROUTE 107
SALEM TURNPIKE
5 FOOT CONTOUR INTERVAL BASED ON MEAN SEA LEVEL (N.G.V.D.) 1000 FOOT GRID BASED ON MASSACHUSETTS COORDINATE SYSTEM (MAINLAND). COMPILED AND CONTROLLED BY JAMES W. SEWALL COMPANY, OLD TOWN, MAINE, BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHS DATED 12-19-78.
400' 0 400' 800'
SCALE:
ELEVATION IN FT. N.G.V.D.
EL. 15
PROTECTIVE BERM EL. 11
10' BUFFER ZONE EL. 9
I-95 SURFACE TO BE REMOVED BY OTHERS PRIOR TO MITIGATION
I-95 FILL BEFORE REMOVAL BY OTHERS
EL. 9
M.H.W.
MARSH GRASS
EXCESS SALTY SAND FROM MITIGATION REMOVAL
CLAM FLATS
FILL TO BE REMOVED FOR MITIGATION
SEA PLANE BASIN
EL. 0
EL. -4
EL. -4
700' 600' 500' 400' 300' 200' 100' 0
MITIGATION SITE PROFILE SECTION A - A



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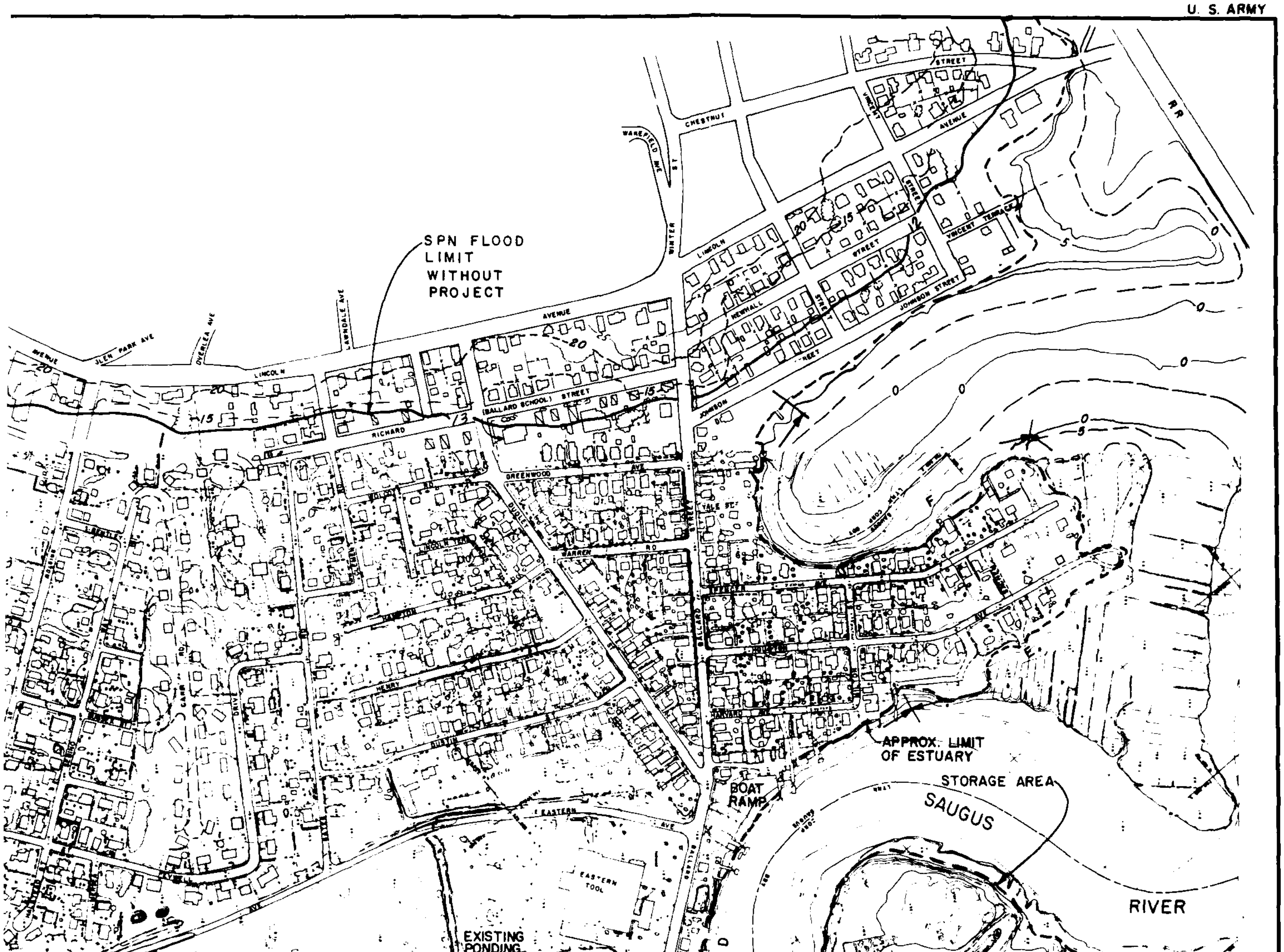
SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY
MITIGATION PLAN
AND PROFILE

PLATE D13

CORPS OF ENGINEERS

U. S. ARMY



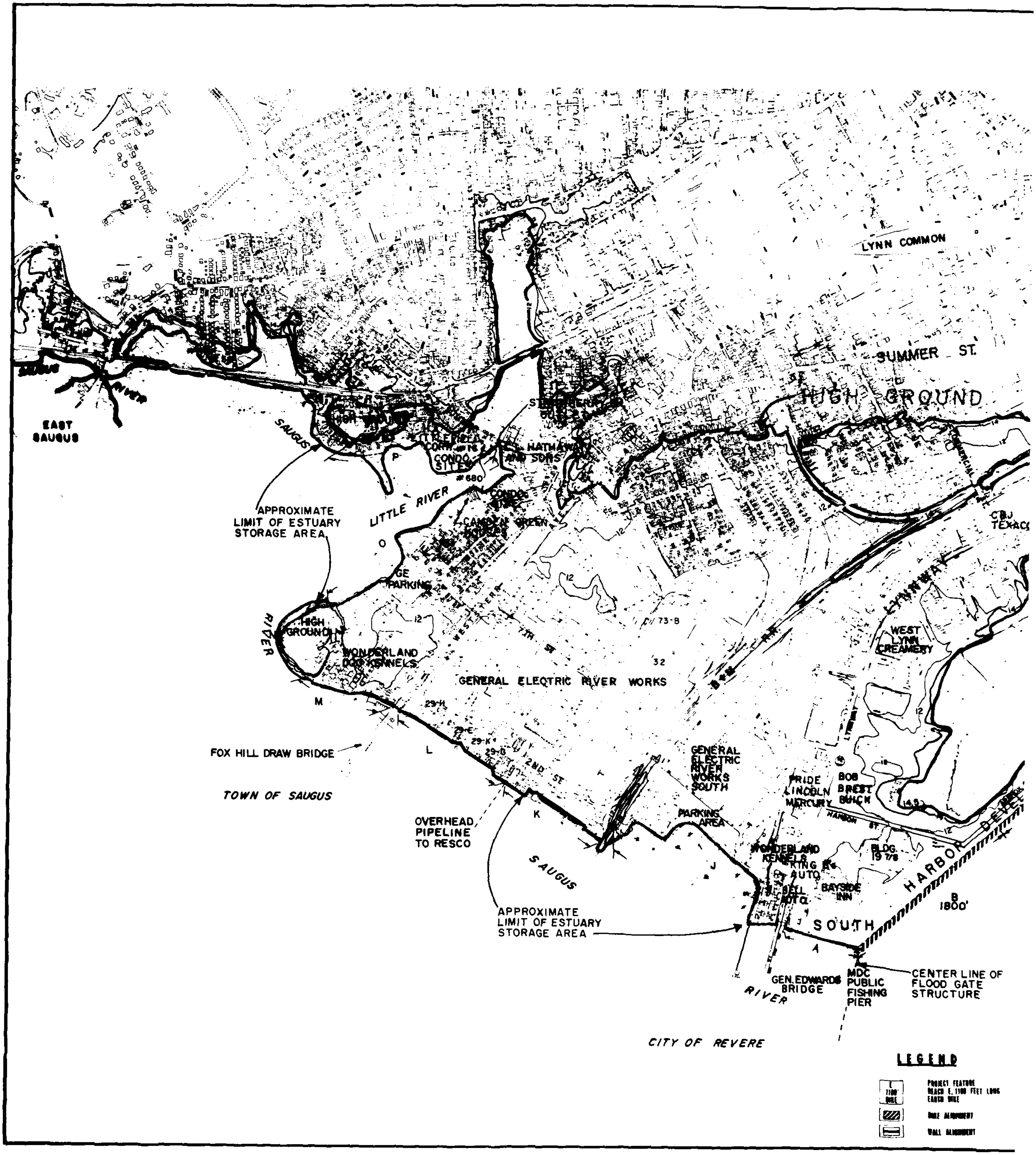
FLOOD DAMAGE REDUCTION STUDY

EAST SAUGUS

ESTUARY

STORAGE AREA

PLATE D14



LYNN COMMON
SUMMER ST.
HIGH GROUND
EAST SAUGUS
SAUGUS RIVER
HIGH GROUND
HATHAWAY AND SONS
CONDO SITE
#680
LITTLE RIVER
CAMDEN GREEN
APPROXIMATE LIMIT OF ESTUARY STORAGE AREA
PARKING
HIGH GROUND
RIVER
WONDERLAND DOG KENNELS
WEST LYNN CREAMERY
GENERAL ELECTRIC RIVER WORKS
73-B
32
LYNNWAY
B&M
CBJ TEXACO
M
FOX HILL DRAW BRIDGE
L
29-H
29-K
29-B
2ND ST.
TOWN OF SAUGUS
GENERAL ELECTRIC RIVER WORKS SOUTH
PRIDE LINCOLN MERCURY
BOB BREST BUICK
PARKING AREA
HARBOR ST.
OVERHEAD PIPELINE TO RESCO
K
SAUGUS
J
WONDERLAND KENNELS
KING AUTO
BELL AUTO
BAYSIDE INN
BLDG. 19 7/8
HARBOR
B
1800'
SOUTH
A
APPROXIMATE LIMIT OF ESTUARY STORAGE AREA
GEN. EDWARDS BRIDGE
MDC PUBLIC FISHING PIER
CENTER LINE OF FLOOD GATE STRUCTURE
RIVER
CITY OF REVERE
LEGEND

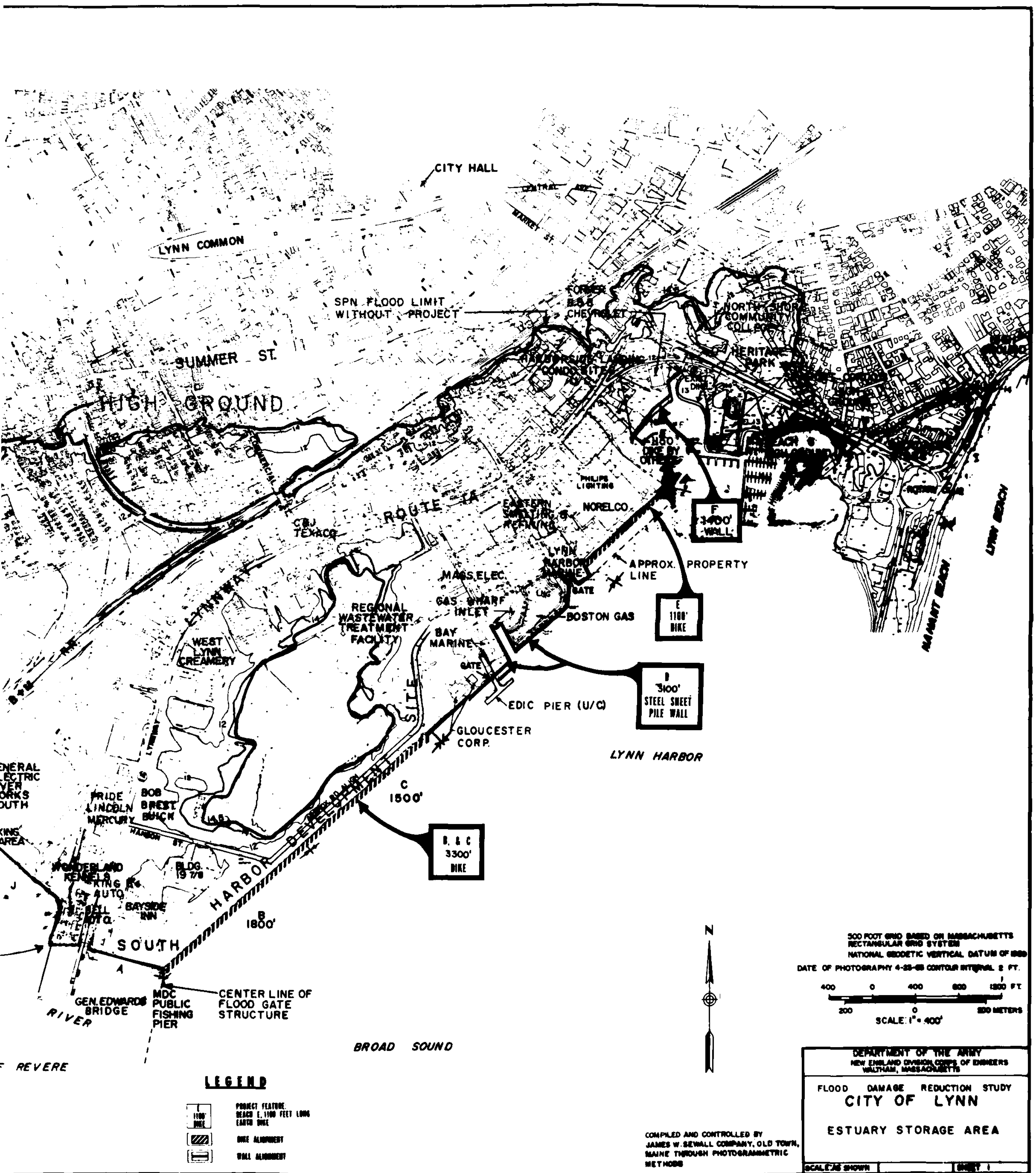
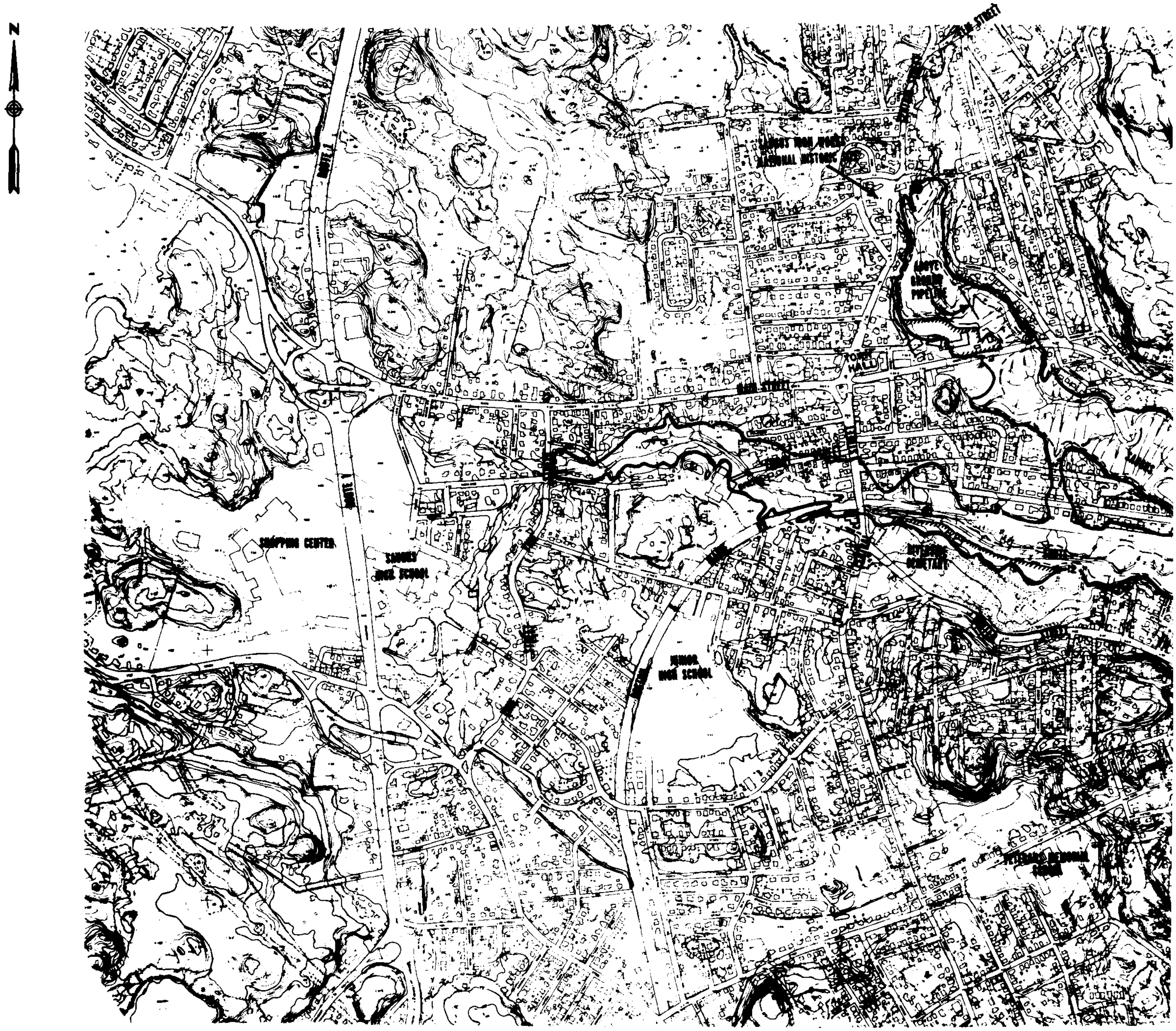
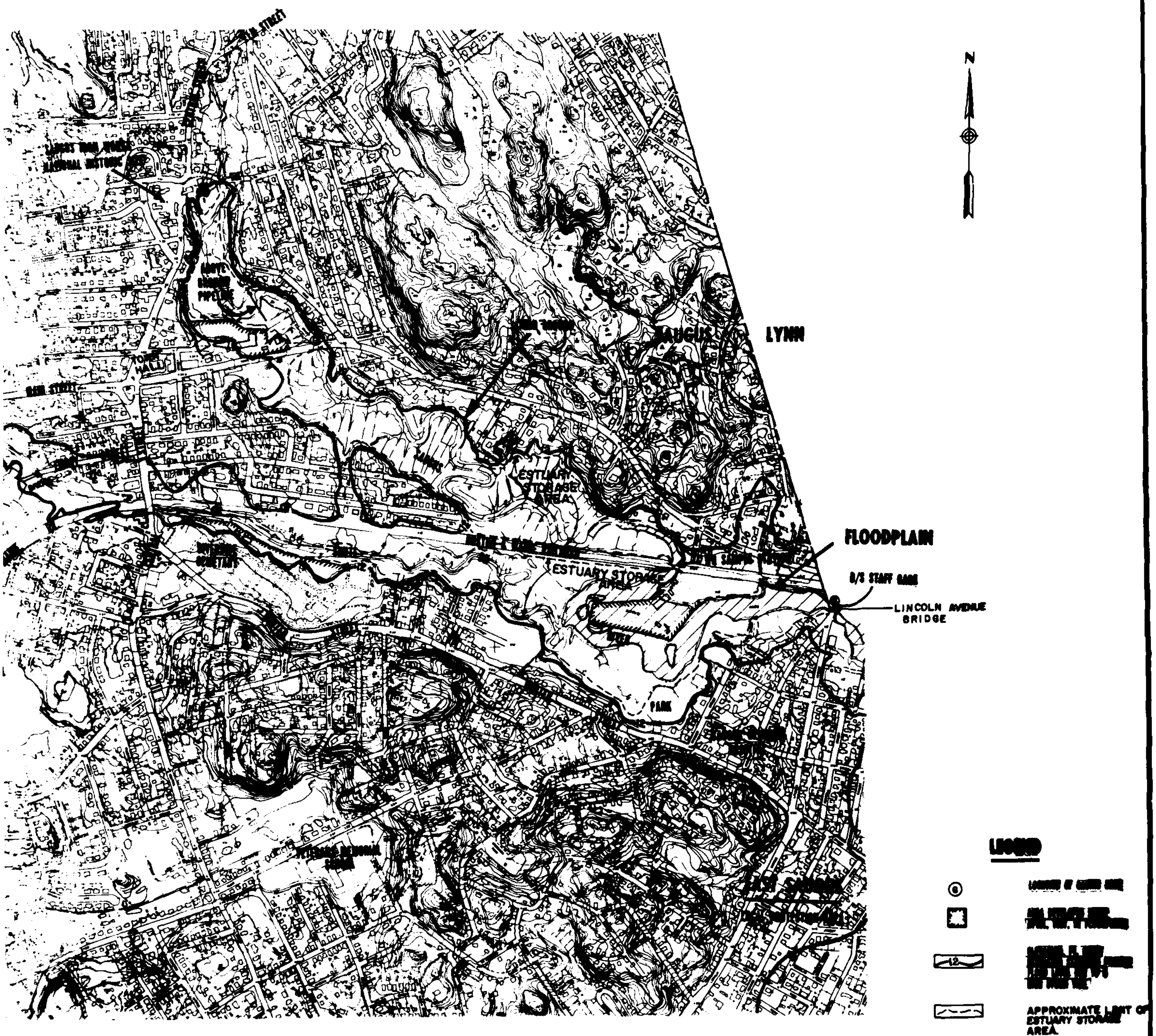

CITY HALL
LYNN COMMON
MARKET ST.
SPN FLOOD LIMIT WITHOUT PROJECT
SUMMER ST.
HIGH GROUND
FORMER B&S CHEVROLET
NORTH SHORE COMMUNITY COLLEGE
HERITAGE PARK
HARBORSIDE LANDING CONDO SITE
PHILIPS LIGHTING
NORELCO
ROUTE 1A
CBJ TEXACO
EASTERN SMELTING & REFINING
F 3400' WALL
LYNN HARBOR MARINE
APPROX. PROPERTY LINE
MASS.ELEC.
GAS WHARF INLET
GATE
BOSTON GAS
E 1100' DIKE
REGIONAL WASTEWATER TREATMENT FACILITY
BAY MARINE
WEST LYNN CREAMERY
LYNNWAY
D 3100' STEEL SHEET PILE WALL
EDIC PIER (U/C)
GLOUCESTER CORP.
LYNN HARBOR
LYNN BEACH
NAHANT BEACH
C 1500'
B & C 3300' DIKE
GENERAL ELECTRIC RIVER WORKS SOUTH
PRIDE LINCOLN MERCURY
BOB BREST BUICK
HARBOR ST.
HARBOR DEVELOPMENT SITE
WONDERLAND KENNELS
KING R. AUTO
BLDG. 19 7/8
BAYSIDE INN
B 1800'
SOUTH
A
GEN. EDWARDS BRIDGE
MDC PUBLIC FISHING PIER
CENTER LINE OF FLOOD GATE STRUCTURE
RIVER
BROAD SOUND
REVERE
N
500 FOOT GRID BASED ON MASSACHUSETTS RECTANGULAR GRID SYSTEM
NATIONAL GEODETIC VERTICAL DATUM OF 1929
CONTOUR INTERVAL 2 FT.
400 0 400 800 1200 FT.
200 0 200 METERS
SCALE: 1" = 400'
LEGEND
PROJECT FEATURE REACH E, 1100 FEET LONG EARTH DIKE
DIKE ALIGNMENT
WALL ALIGNMENT
COMPILED AND CONTROLLED BY JAMES W. SEWALL COMPANY, OLD TOWN, MAINE THROUGH PHOTOGRAMMETRIC METHODS
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS
FLOOD DAMAGE REDUCTION STUDY
CITY OF LYNN
ESTUARY STORAGE AREA
SCALE: AS SHOWN
SHEET 1

PLATE D15



TOWN of SAUGUS, MASS.



ALONG SHUTE BROOK BETWEEN CENTRAL STREET AND VINE STREET IS A POTENTIAL AREA AFFECTED BY HIGH WATERSHED RUNOFF COINCIDENT WITH HIGH STORM TIDES.

SCALE: 1" = 400'

CONTOUR INTERVAL = 5 FEET

FROM PHOTOGRAPHY FLOWN IN APRIL 1967.

DATE OF LAST STORAGE AREA REVISION: FEB 1967.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

UPPER SAUGUS RIVER

ESTUARY STORAGE AREA

PLATE D16

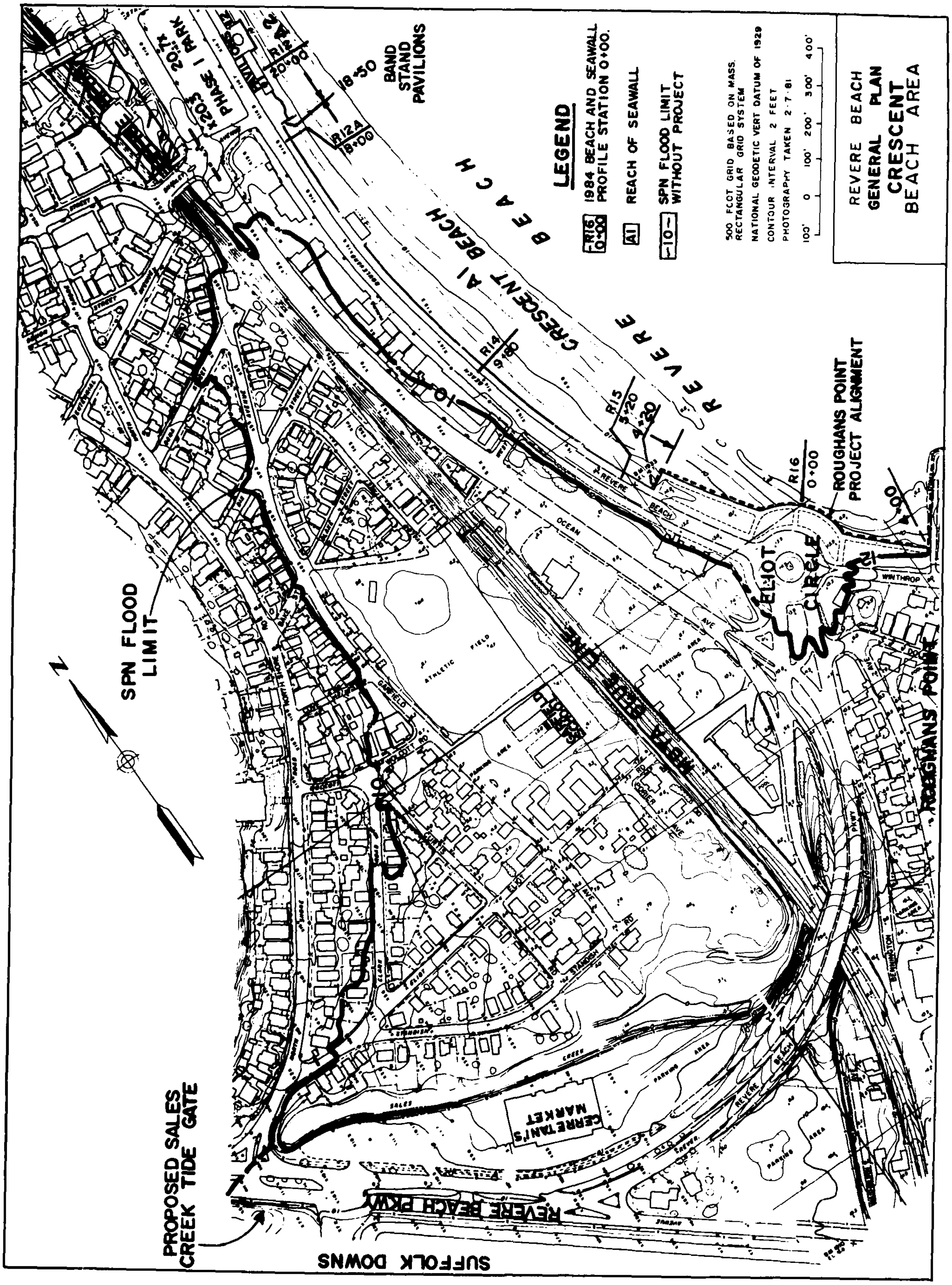
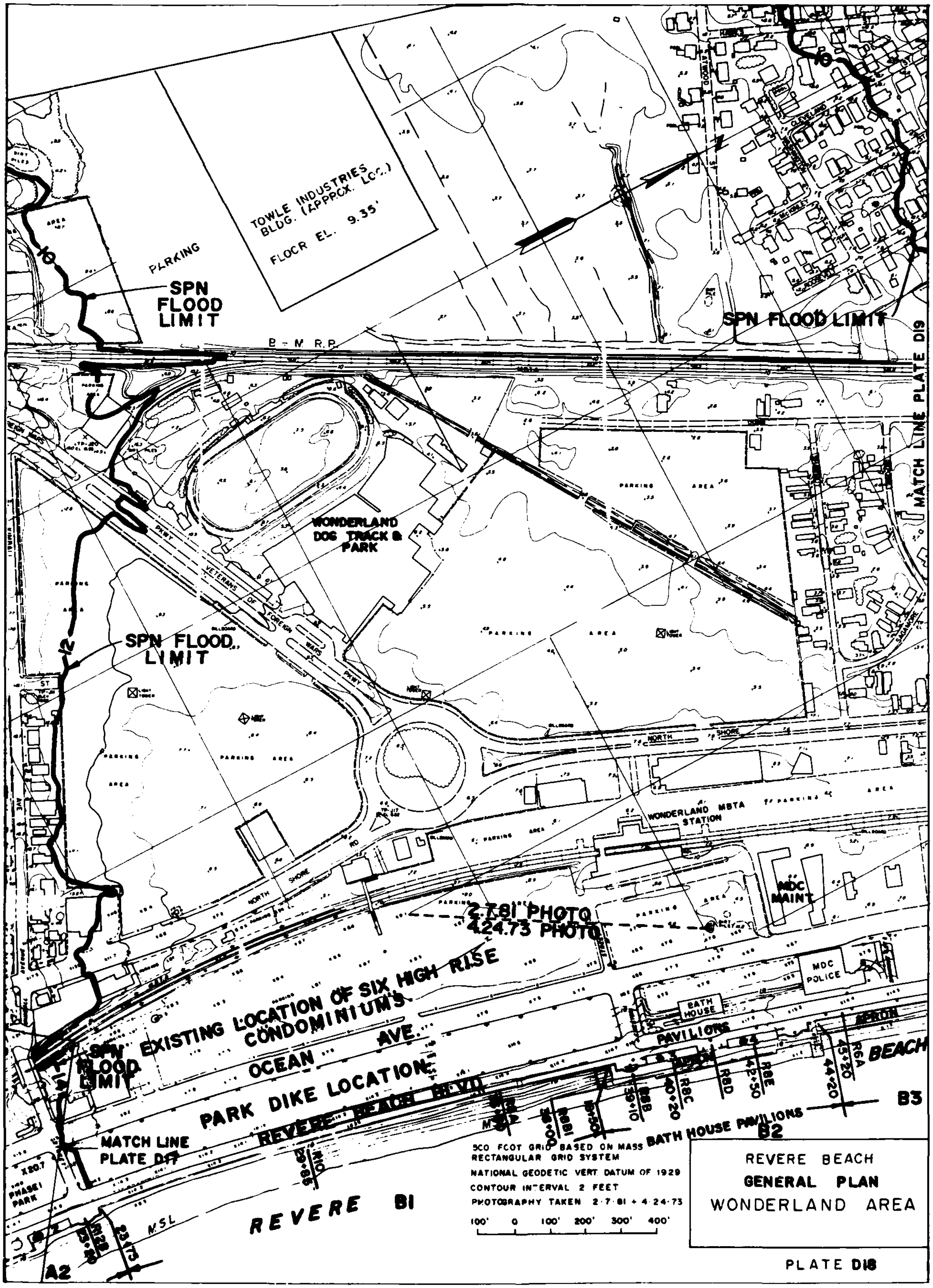
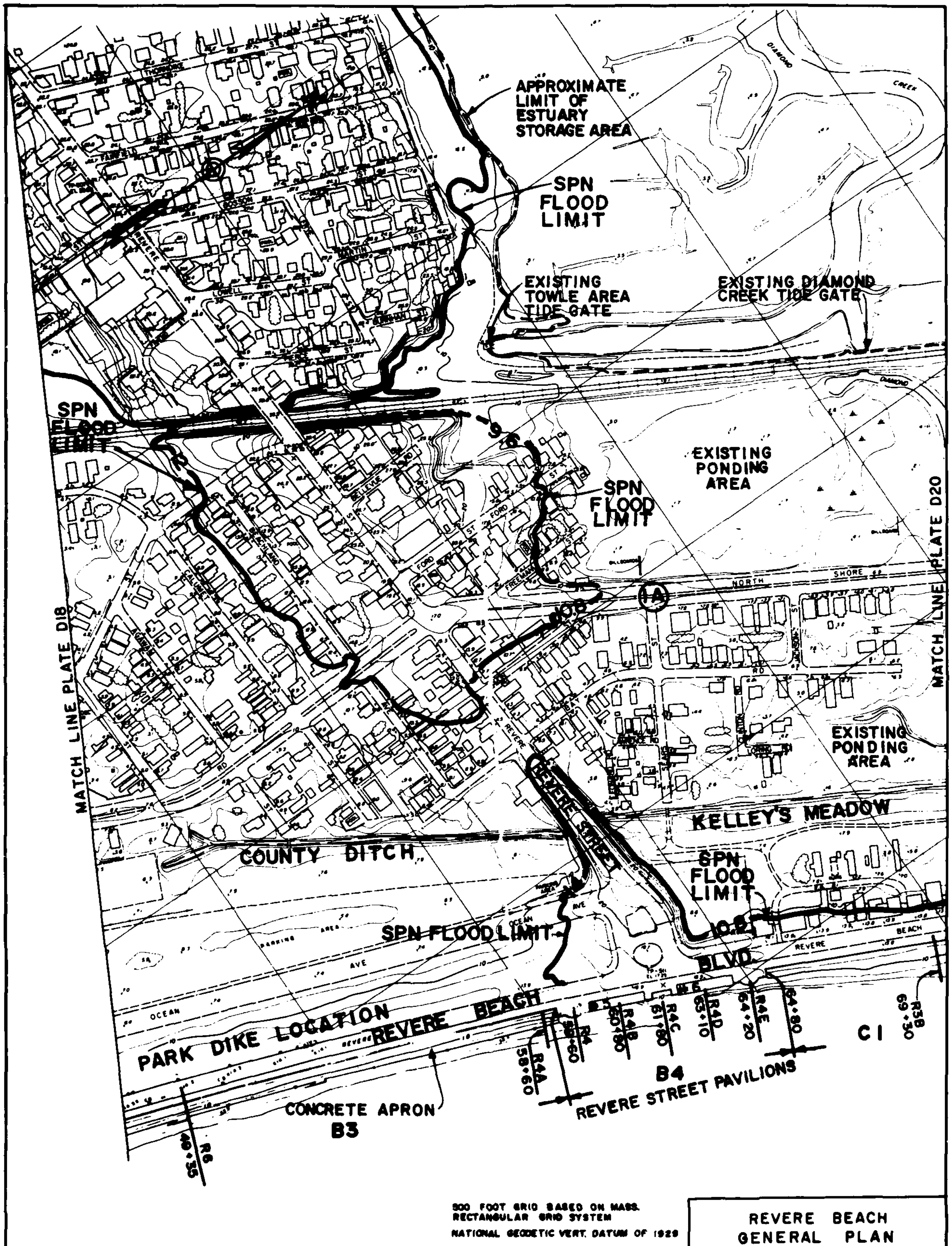

LEGEND
R16 0+00 1984 BEACH AND SEAWALL PROFILE STATION 0+00.
A1 REACH OF SEAWALL
10 SPN FLOOD LIMIT WITHOUT PROJECT
500 FOOT GRID BASED ON MASS. RECTANGULAR GRID SYSTEM
NATIONAL GEODETIC VERT DATUM OF 1929
CONTOUR INTERVAL 2 FEET
PHOTOGRAPHY TAKEN 2-7-81
100' 0 100' 200' 300' 400'
REVERE BEACH
GENERAL PLAN
CRESCENT
BEACH AREA
PLATE D17
REVERE BEACH
CRESCENT A1 BEACH
BAND STAND PAVILIONS
PHASE I PARK
ROUGHANS POINT PROJECT ALIGNMENT
ROUGHANS POINT
ELIOT CIRCLE
SPN FLOOD LIMIT
CERRETANI'S MARKET
REVERE BEACH PKWY
PROPOSED SALES CREEK TIDE GATE
SUFFOLK DOWNS
ATHLETIC FIELD
BLUE LINE

PLATE D17

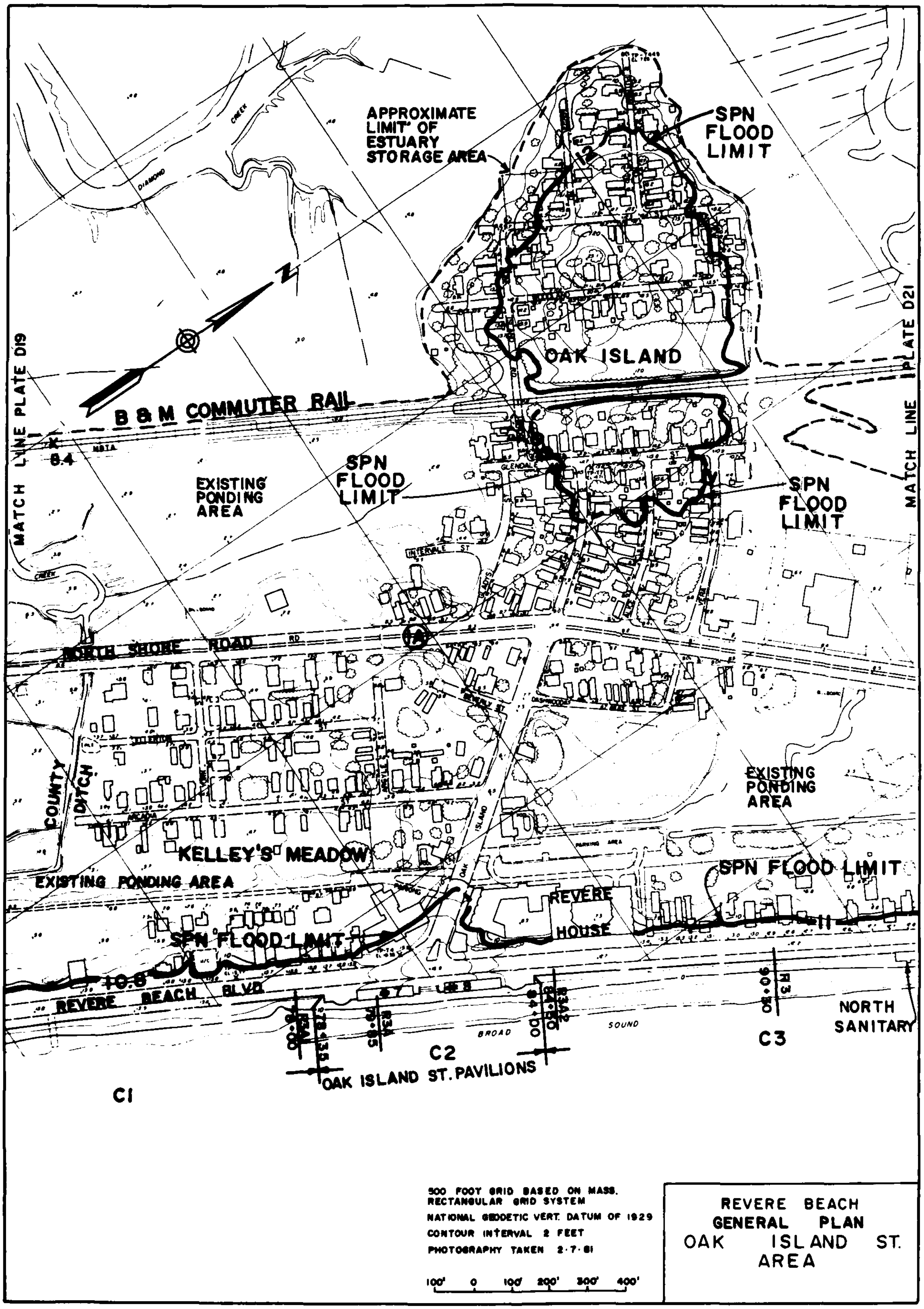


REVERE BEACH
GENERAL PLAN
WONDERLAND AREA

PLATE D18

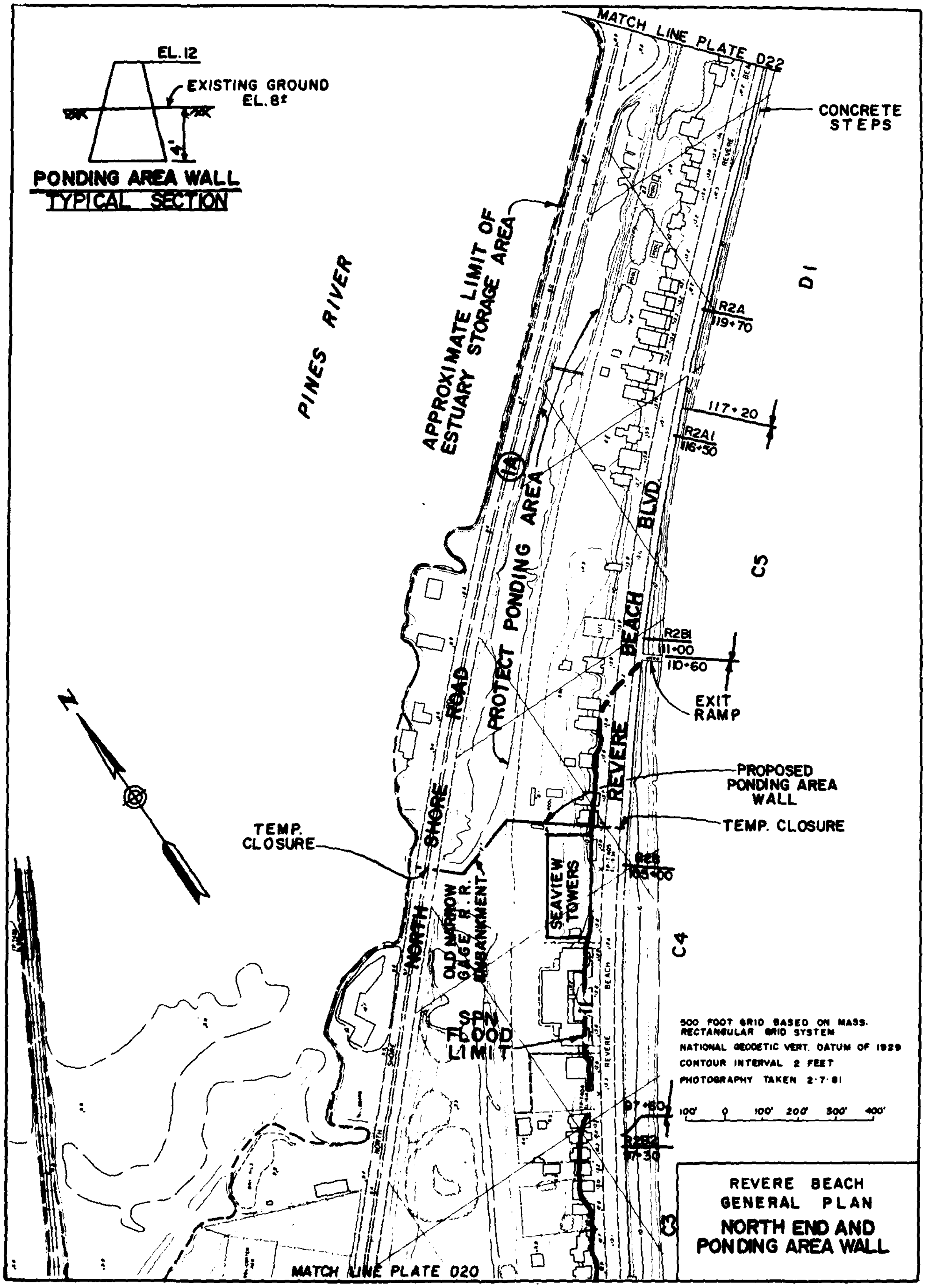


REVERE BEACH
GENERAL PLAN
REVERE ST. AREA



REVERE BEACH
GENERAL PLAN
OAK ISLAND ST.
AREA

PLATE D20


EL. 12
EXISTING GROUND
EL. 8±
4'
PONDING AREA WALL
TYPICAL SECTION
MATCH LINE PLATE D22
CONCRETE STEPS
PINES RIVER
APPROXIMATE LIMIT OF ESTUARY STORAGE AREA
D1
R2A
119+70
117+20
R2A1
116+50
PROTECT PONDING AREA
REVERE BEACH BLVD
C5
R2B1
111+00
110+60
EXIT RAMP
NORTH SHORE ROAD
PROPOSED PONDING AREA WALL
TEMP. CLOSURE
TEMP. CLOSURE
SEAVIEW TOWERS
OLD NARROW GAGE R.R. EMBANKMENT
C4
SPN FLOOD LIMIT
500 FOOT GRID BASED ON MASS. RECTANGULAR GRID SYSTEM
NATIONAL GEODETIC VERT. DATUM OF 1929
CONTOUR INTERVAL 2 FEET
PHOTOGRAPHY TAKEN 2·7·81
100' 0 100' 200' 300' 400'
97+60
R2B2
97+30
C3
MATCH LINE PLATE D20
REVERE BEACH
GENERAL PLAN
NORTH END AND
PONDING AREA WALL

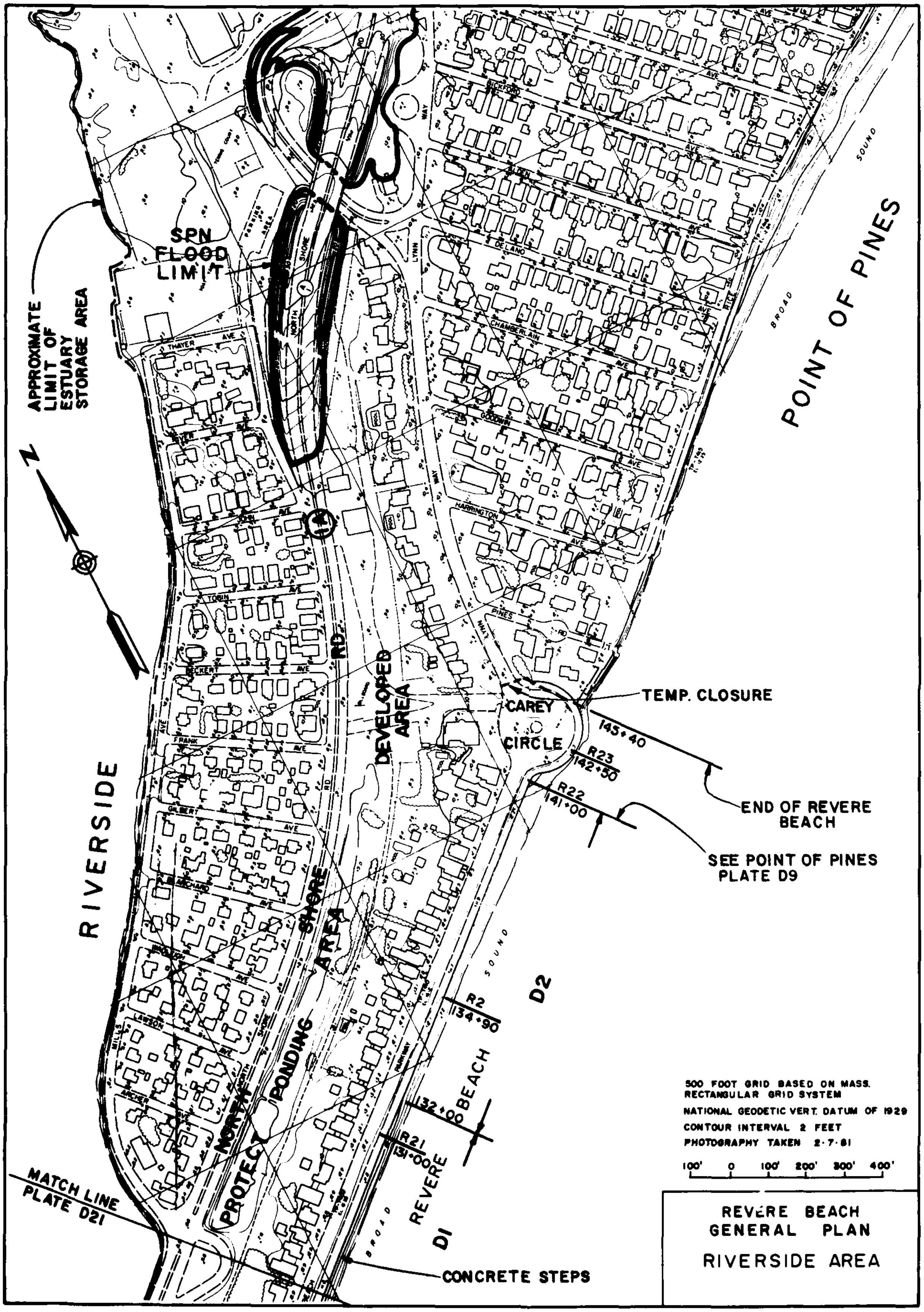
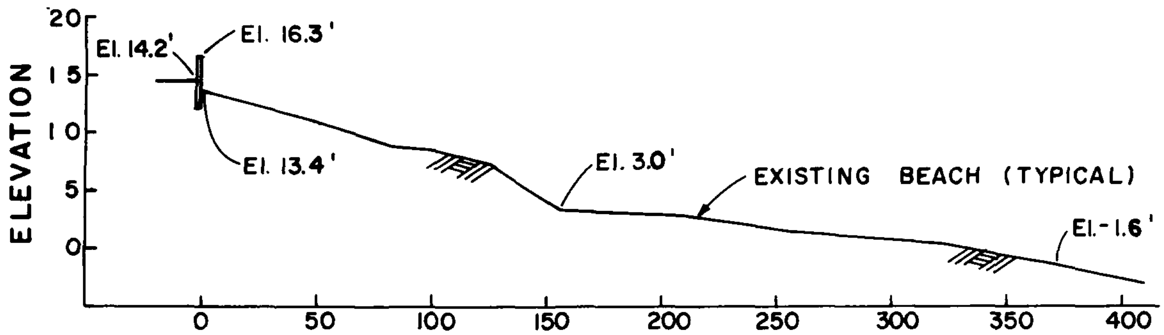
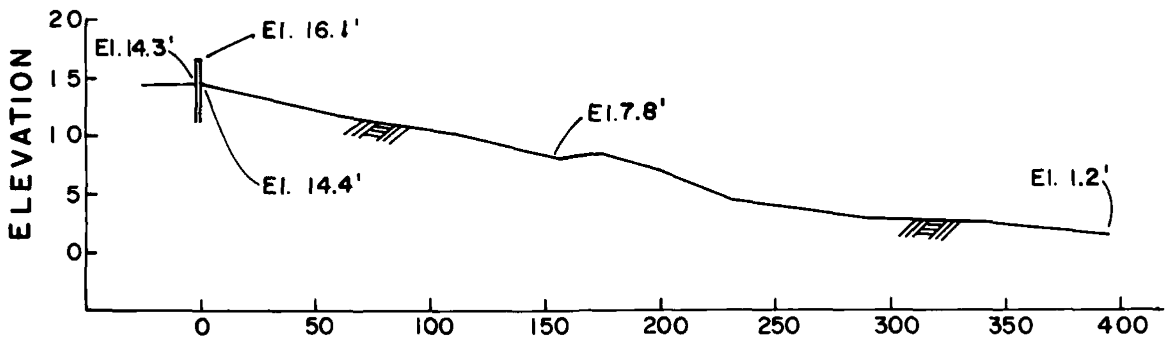

SPN
FLOOD
LIMIT
APPROXIMATE
LIMIT OF
ESTUARY
STORAGE AREA
POINT OF PINES
BROAD
SOUND
DEVELOPED
AREA
CAREY
CIRCLE
TEMP. CLOSURE
145+40
R23
142+50
R22
141+00
END OF REVERE
BEACH
SEE POINT OF PINES
PLATE D9
RIVERSIDE
NORTH SHORE RD
NORTH SHORE
PROTECT PONDING AREA
D2
R2
134+90
132+00
BEACH
R21
131+00
REVERE
D1
MATCH LINE
PLATE D21
CONCRETE STEPS
500 FOOT GRID BASED ON MASS. RECTANGULAR GRID SYSTEM
NATIONAL GEODETIC VERT. DATUM OF 1929
CONTOUR INTERVAL 2 FEET
PHOTOGRAPHY TAKEN 2-7-81
100' 0 100' 200' 300' 400'
REVERE BEACH
GENERAL PLAN
RIVERSIDE AREA

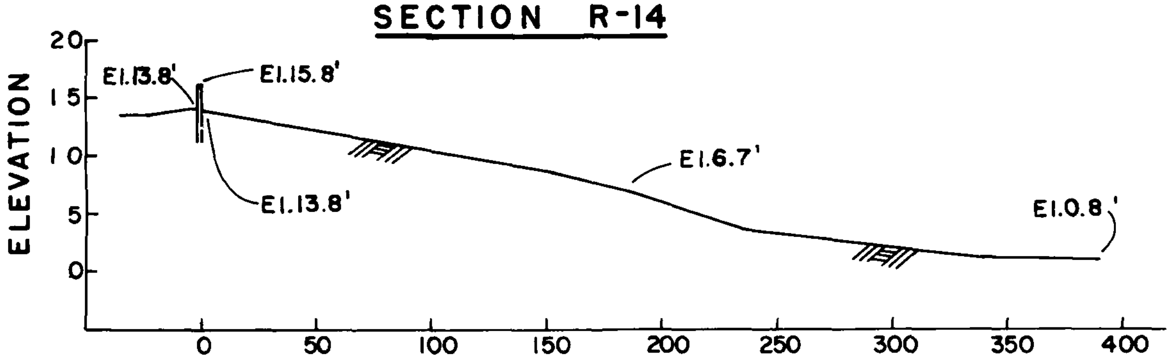
PLATE D22



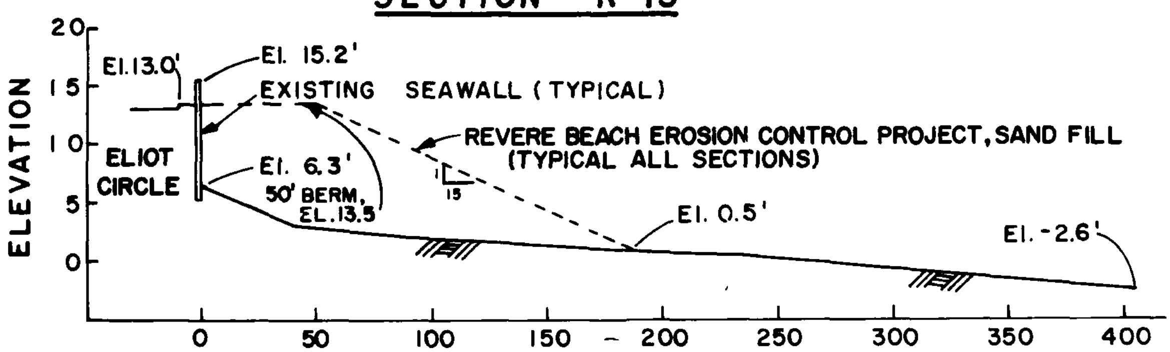
SECTION R-12-A



SECTION R-14

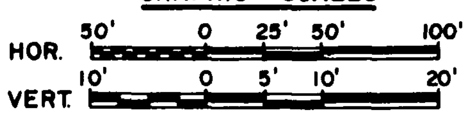


SECTION R-15



SECTION R-16

GRAPHIC SCALES



NOTE:

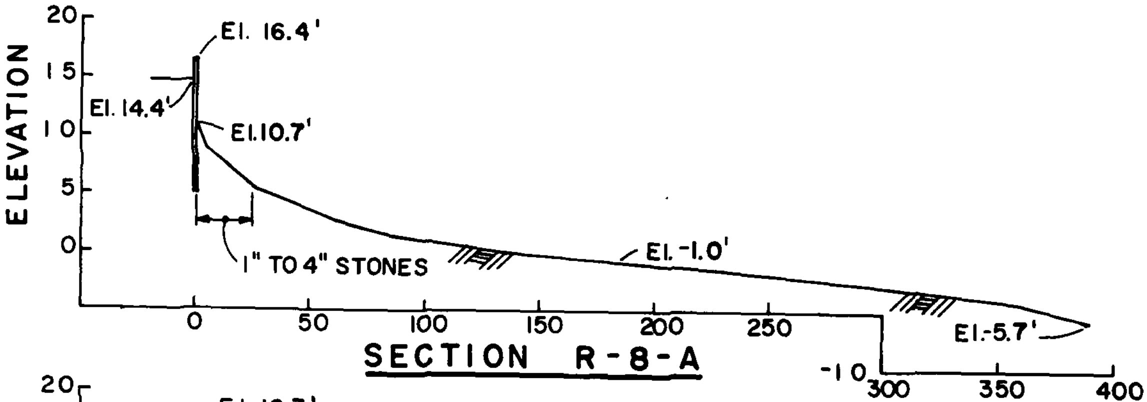
Elevations are in feet and are based on the National Geodetic Vertical Datum (N.G.V.D.).

REVERE BEACH
MASSACHUSETTS

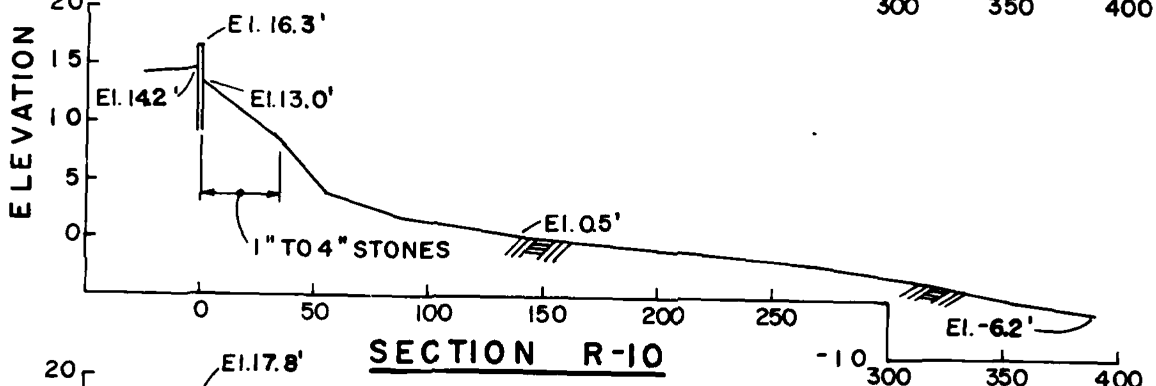
JUNE, 1984 SURVEY

SECTIONS NO. 1

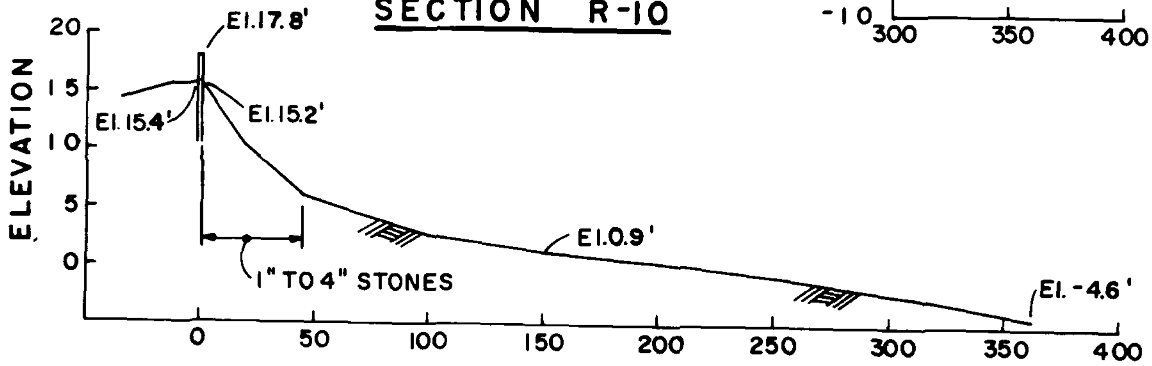
PLATE: D23



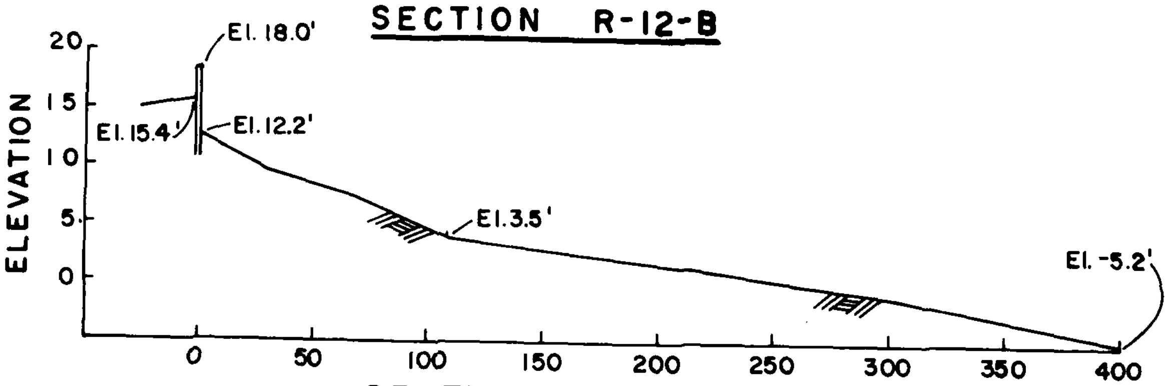
SECTION R-8-A



SECTION R-10

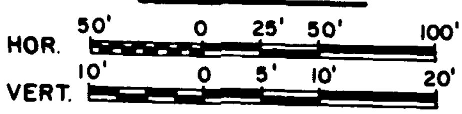


SECTION R-12-B



SECTION R-12

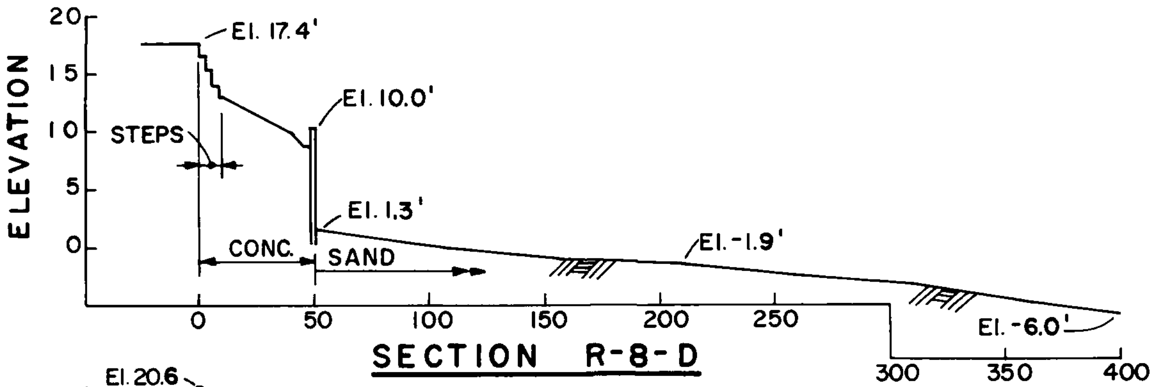
GRAPHIC SCALES



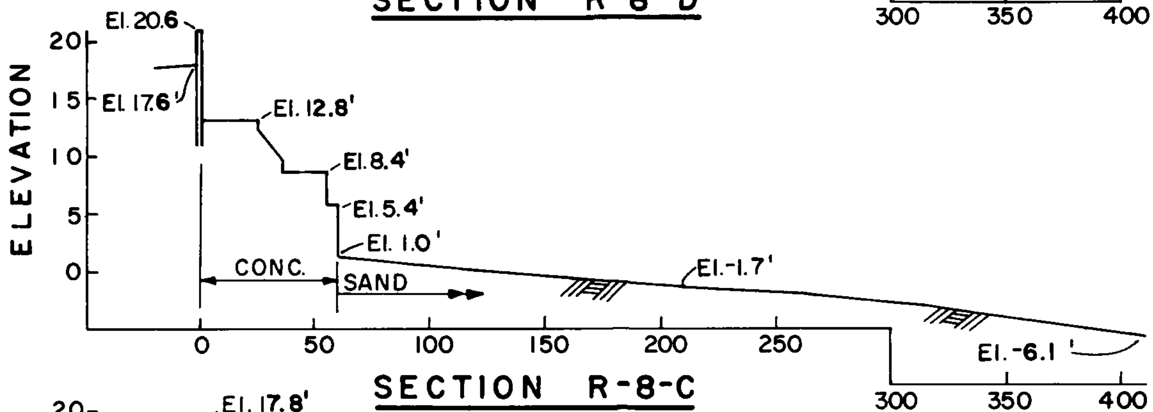
NOTE:
Elevations are in feet and are based on the National Geodetic Vertical Datum (N.G.V.D.).

REVERE BEACH
MASSACHUSETTS
JUNE, 1984 SURVEY
SECTIONS NO. 2

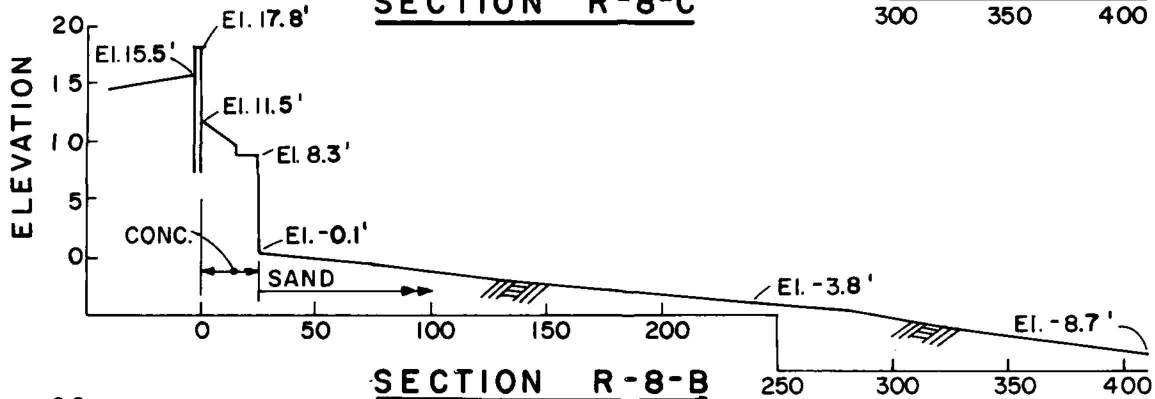
PLATE: D24



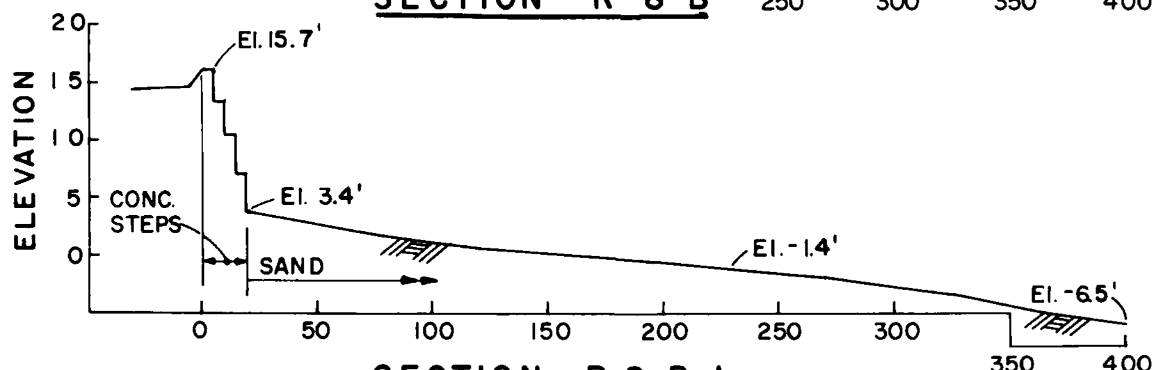
SECTION R-8-D



SECTION R-8-C

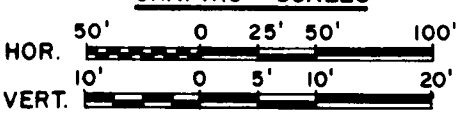


SECTION R-8-B



SECTION R-8-B-1

GRAPHIC SCALES



NOTE:

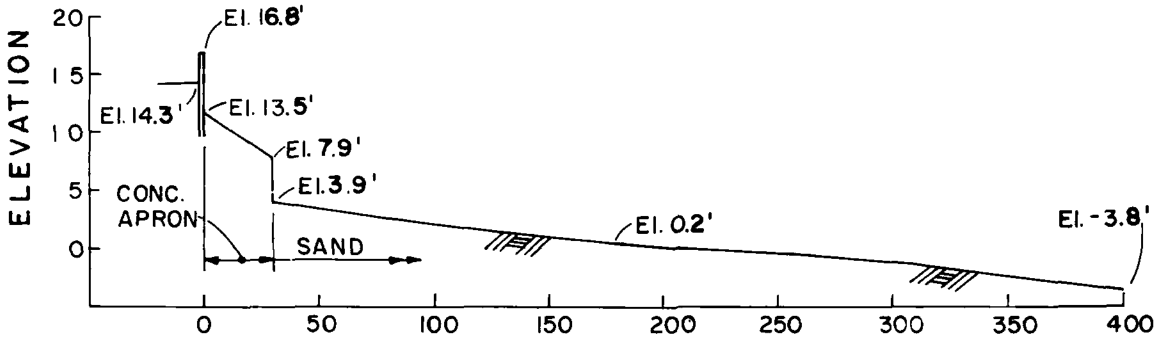
Elevations are in feet and are based on the National Geodetic Vertical Datum (N.G.V.D.).

REVERE BEACH
MASSACHUSETTS

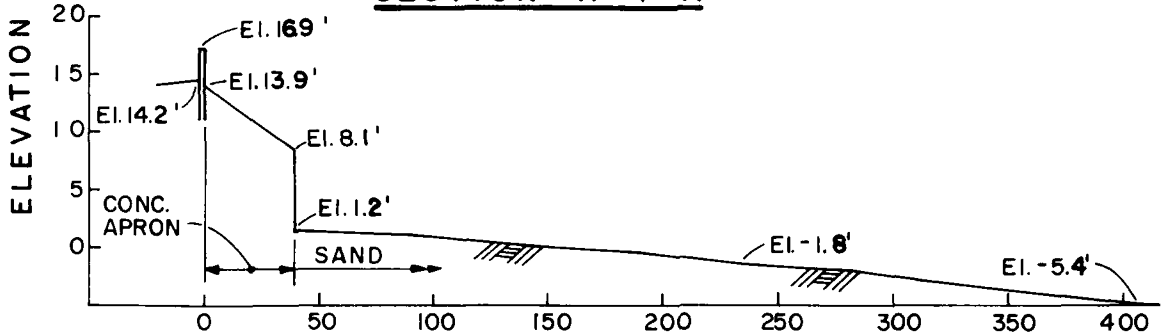
JUNE, 1984 SURVEY

SECTIONS NO. 3

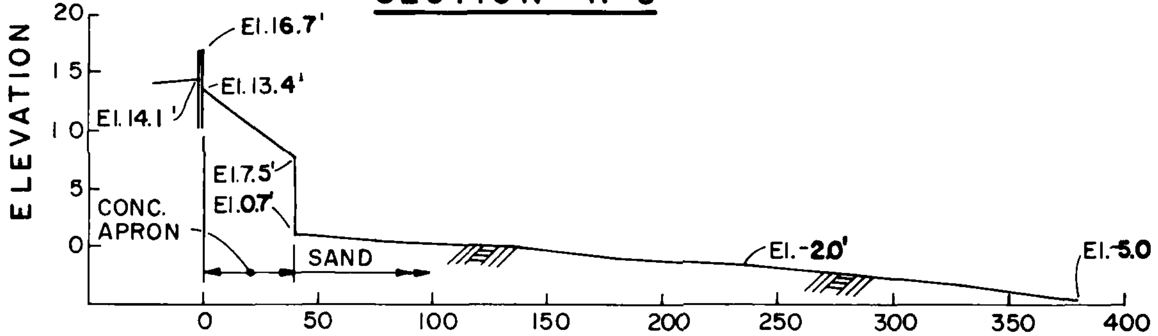
PLATE: D25



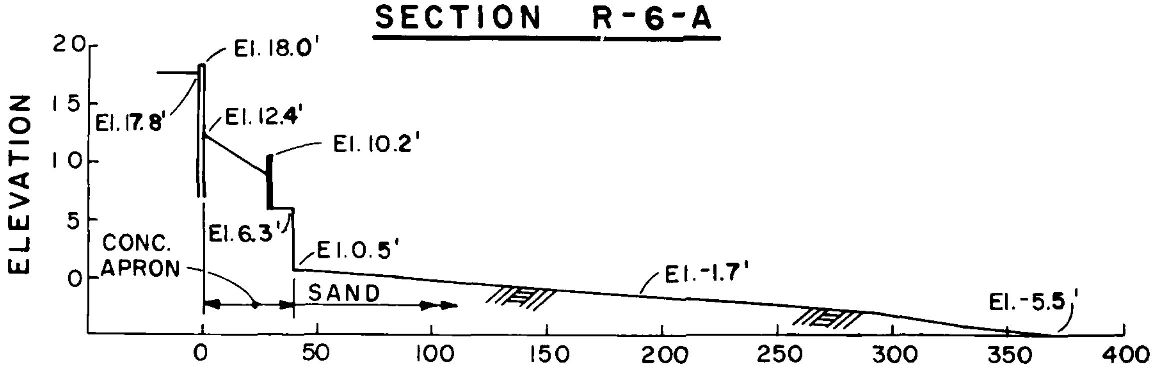
SECTION R-4-A



SECTION R-6

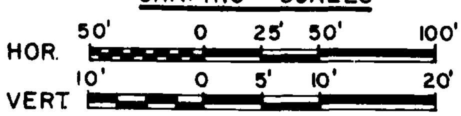


SECTION R-6-A



SECTION R-8-E

GRAPHIC SCALES



NOTE:

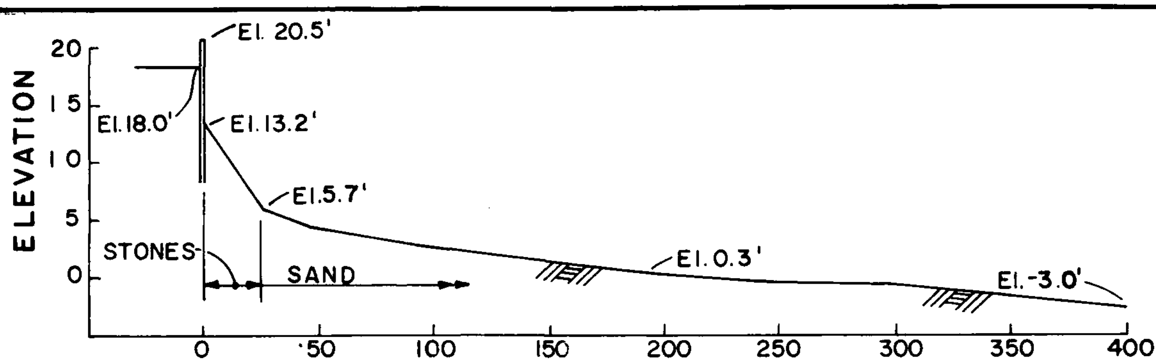
Elevations are in feet and are based on the National Geodetic Vertical Datum (N.G.V.D.).

REVERE BEACH
MASSACHUSETTS

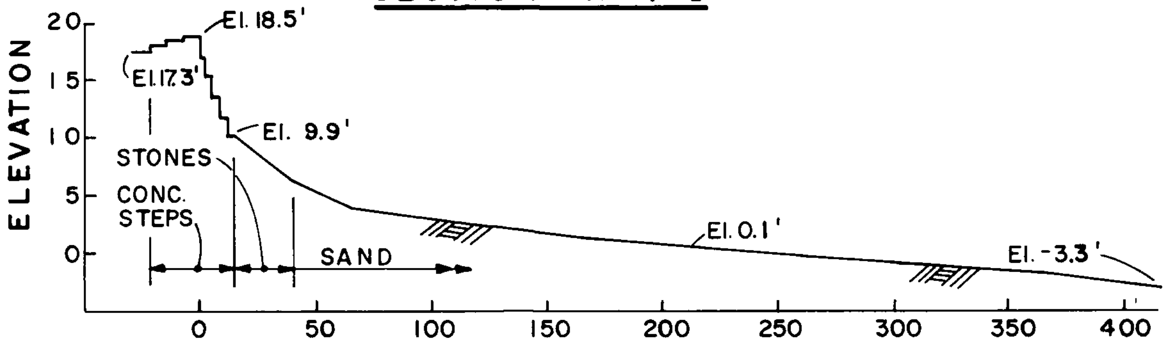
JUNE, 1984 SURVEY

SECTIONS NO. 4

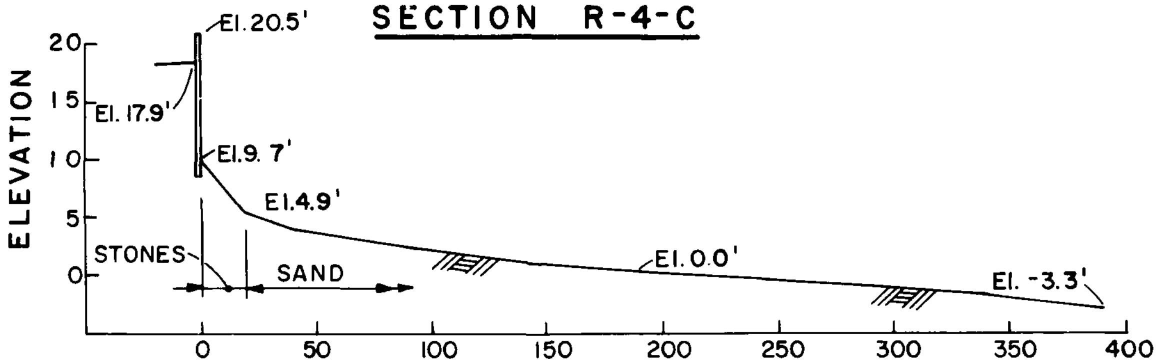
PLATE: D26



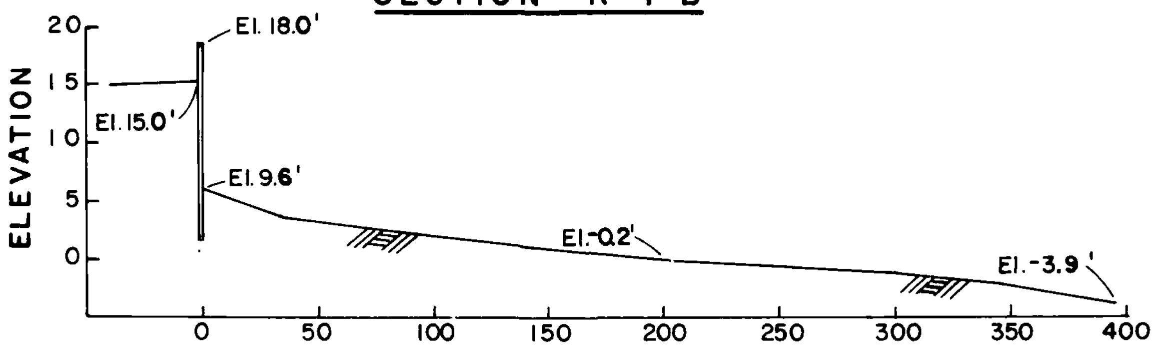
SECTION R-4-D



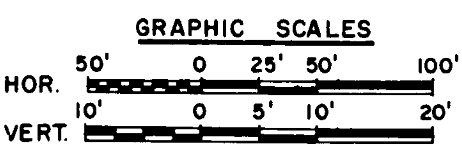
SECTION R-4-C



SECTION R-4-B



SECTION R-4



NOTE:

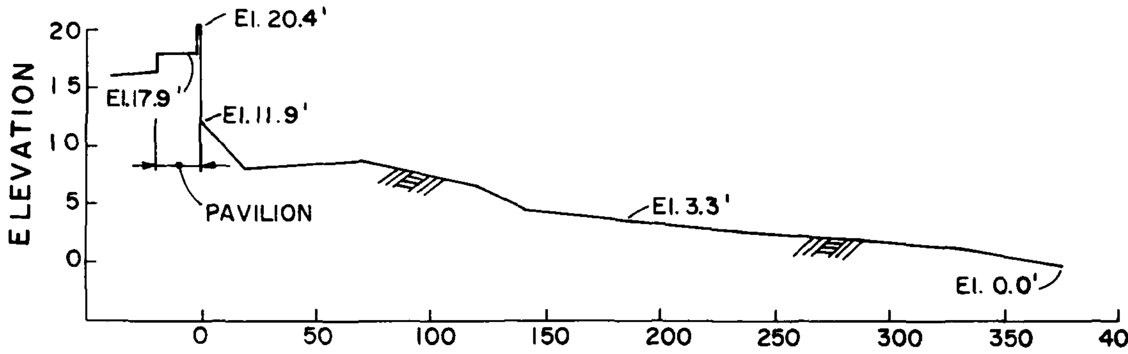
Elevations are in feet and are based on the National Geodetic Vertical Datum (N.G.V.D.).

REVERE BEACH
MASSACHUSETTS

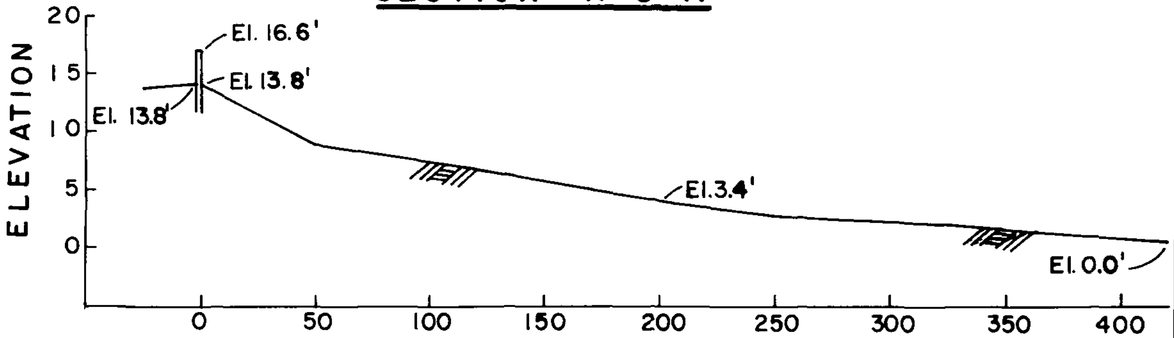
JUNE, 1984 SURVEY

SECTIONS NO. 5

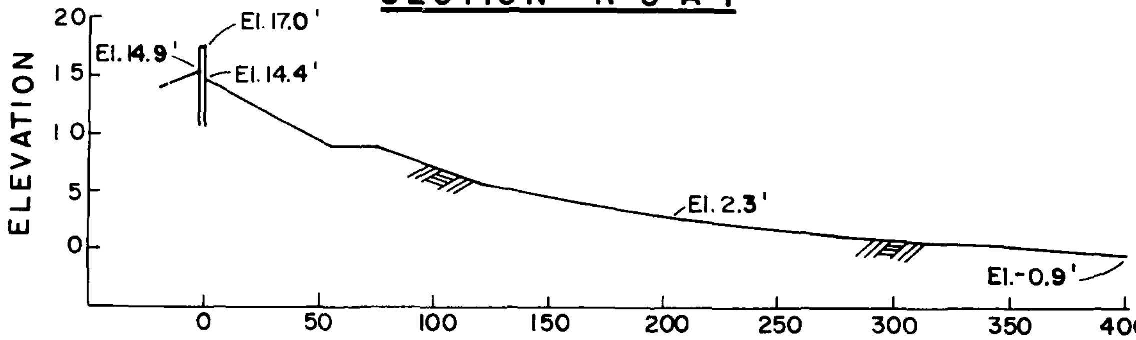
PLATE: D27



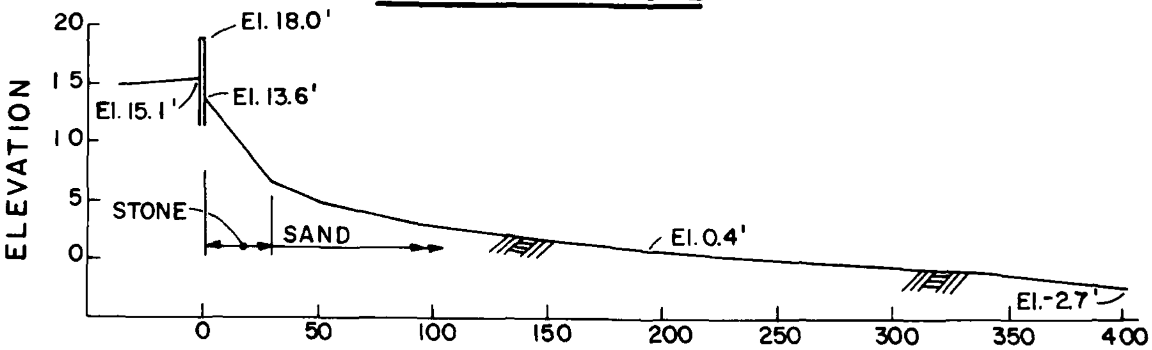
SECTION R-3-A



SECTION R-3-A-1

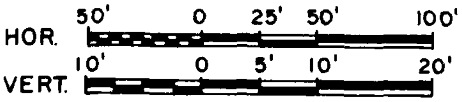


SECTION R-3-B



SECTION R-4-E

GRAPHIC SCALES



NOTE:

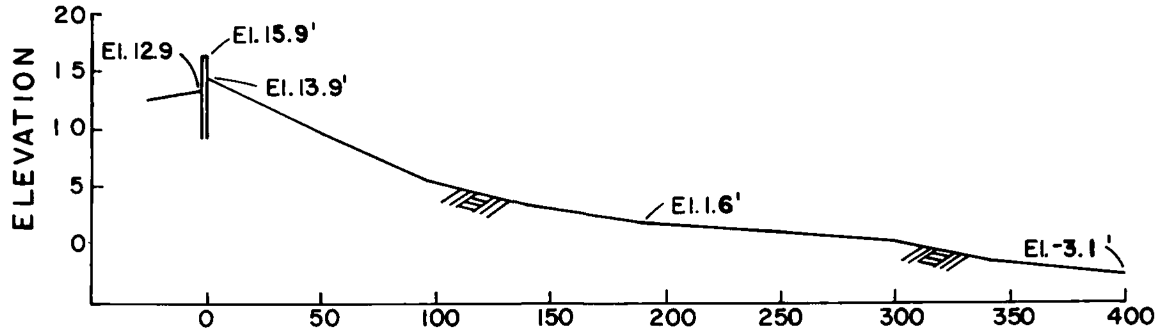
Elevations are in feet and are based on the National Geodetic Vertical Datum (N.G.V.D.).

REVERE BEACH
MASSACHUSETTS

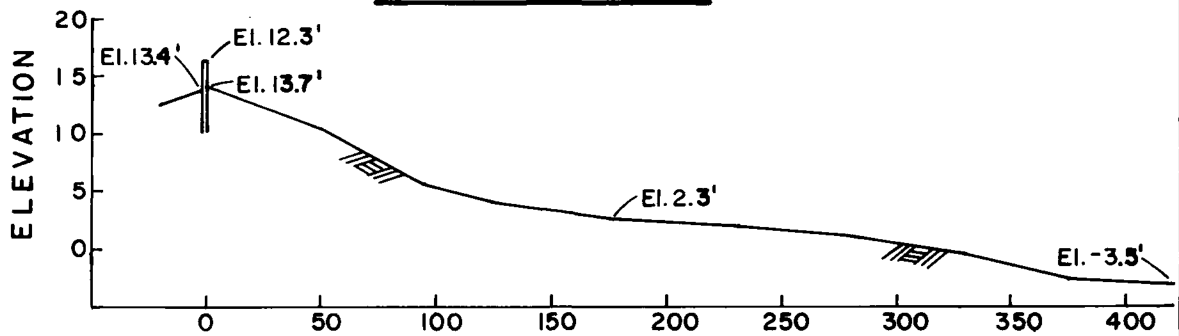
JUNE, 1984 SURVEY

SECTIONS NO. 6

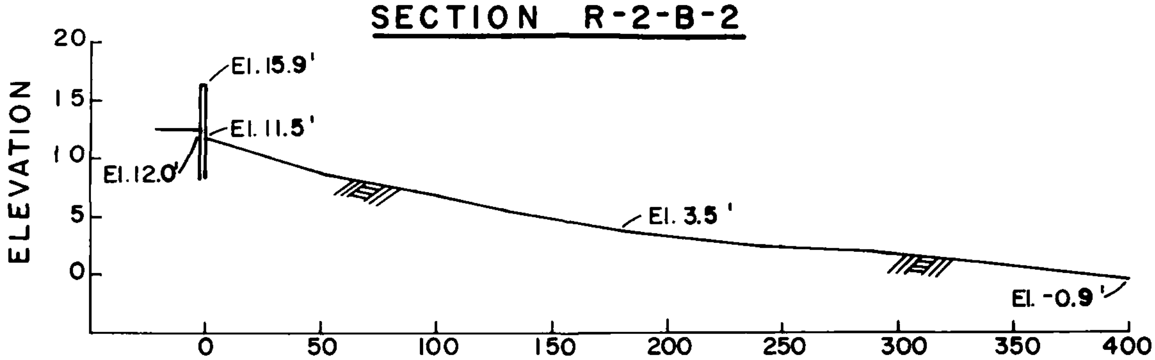
PLATE: D28



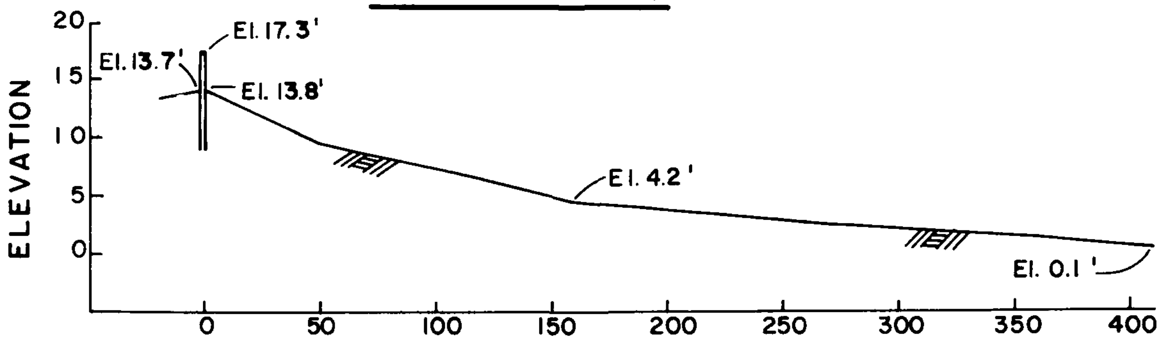
SECTION R-2-B



SECTION R-2-B-2



SECTION R-3



SECTION R-3-A-2

GRAPHIC SCALES

HOR. 50' 0 25' 50' 100'

VERT. 10' 0 5' 10' 20'

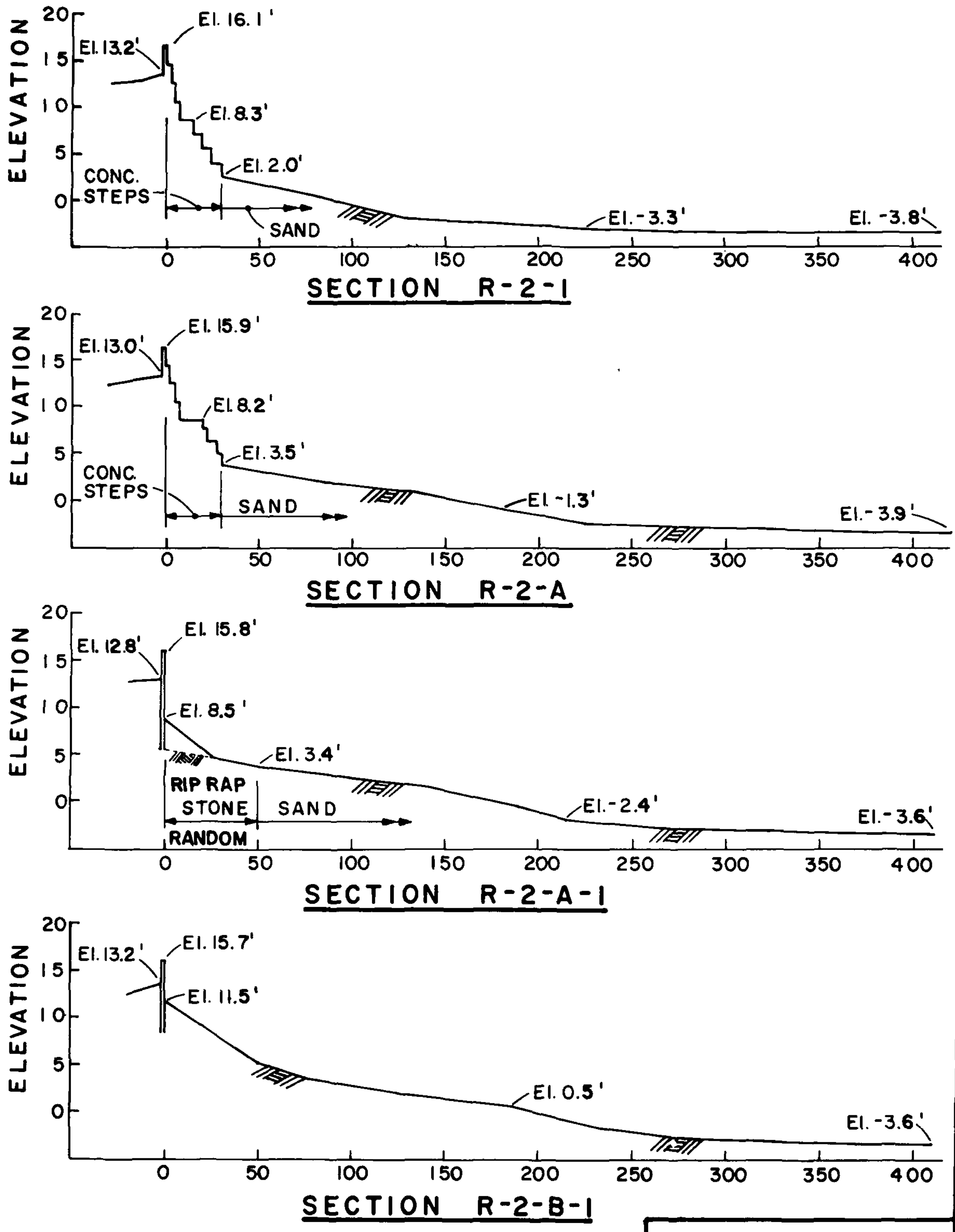
NOTE:
Elevations are in feet and are based on the National Geodetic Vertical Datum (N.G.V.D.).

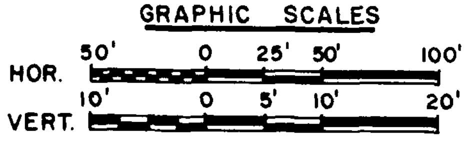
REVERE BEACH
MASSACHUSETTS

JUNE, 1984 SURVEY

SECTIONS NO. 7

PLATE: D29



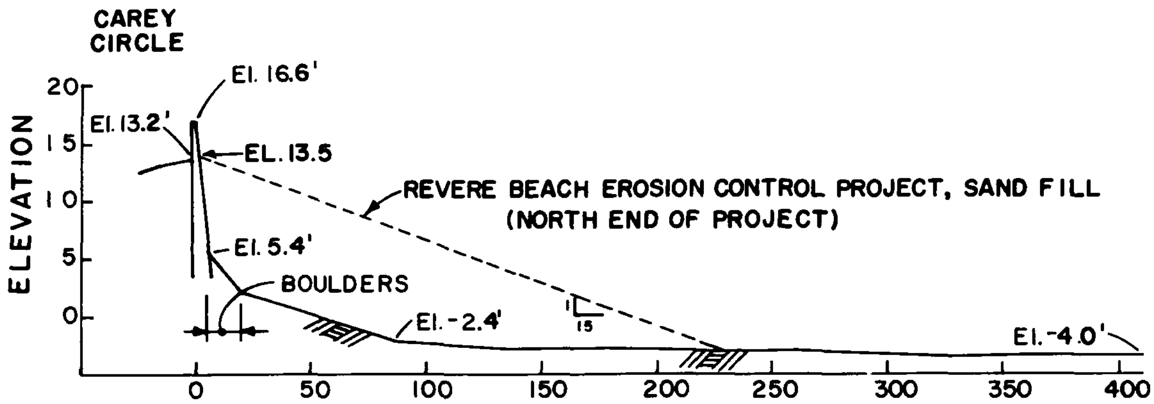


NOTE:

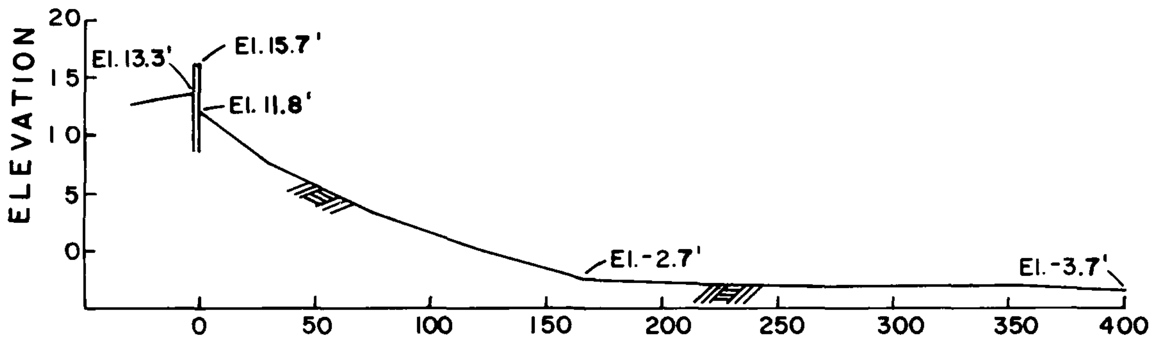
Elevations are in feet and are based on the National Geodetic Vertical Datum (N.G.V.D.).

REVERE BEACH
MASSACHUSETTS
JUNE, 1984 SURVEY
SECTIONS NO. 8

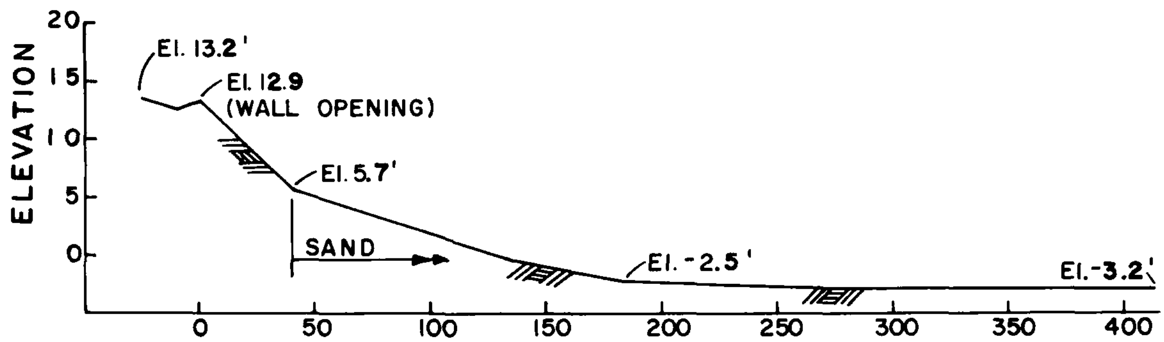
PLATE: D30



SECTION R-2-3



SECTION R-2-2



SECTION R-2

GRAPHIC SCALES

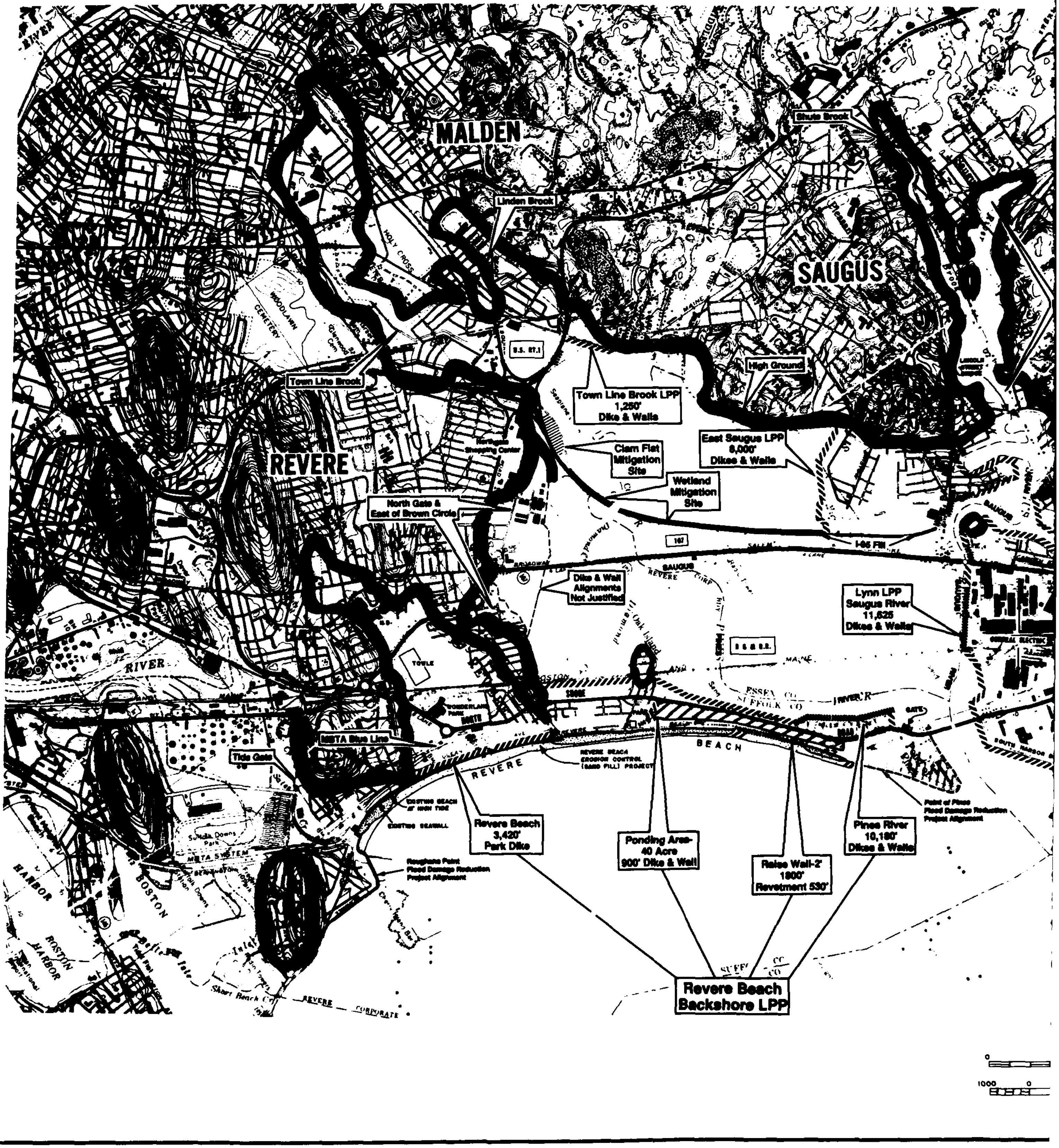
HOR. 50' 0 25' 50' 100'

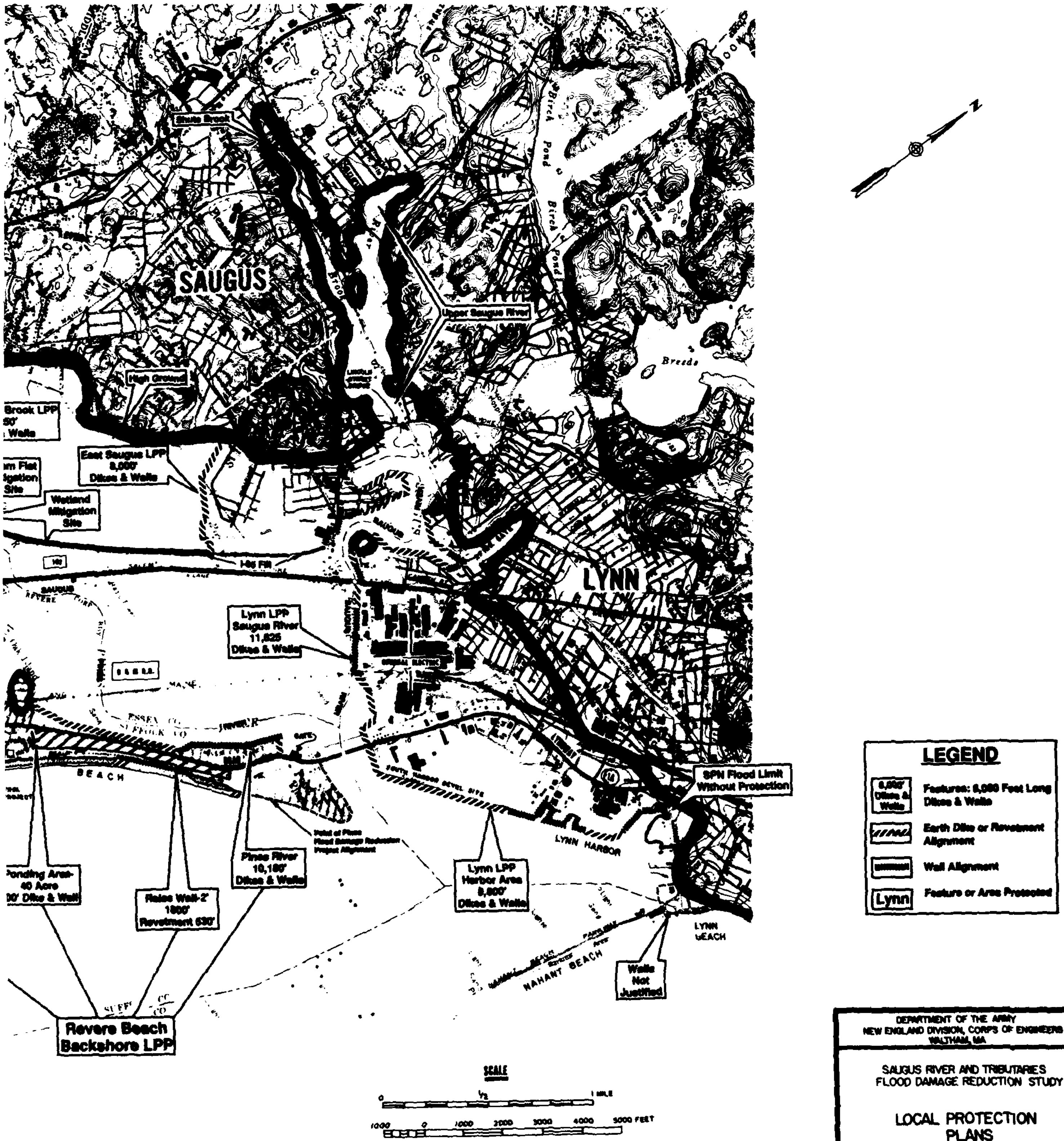
VERT. 10' 0 5' 10' 20'

NOTE:
Elevations are in feet and are based on the National Geodetic Vertical Datum (N.G.V.D.).

REVERE BEACH
MASSACHUSETTS
JUNE, 1984 SURVEY
SECTIONS NO. 9

PLATE: D31


MALDEN
SAUGUS
REVERE
Shute Brook
Linden Brook
Town Line Brook
High Ground
Town Line Brook LPP
1,250'
Dike & Walls
East Saugus LPP
8,000'
Dikes & Walls
Clam Flat
Mitigation
Site
Wetland
Mitigation
Site
North Gate &
East of Brown Circle
Dike & Wall
Alignments
Not Justified
Lynn LPP
Saugus River
11,625
Dikes & Walls
MBTA Blue Line
Tide Gate
REVERE BEACH
EROSION CONTROL
(SAND FILL) PROJECT
Revere Beach
3,420'
Park Dike
Ponding Area-
40 Acre
900' Dike & Wall
Raise Wall-2'
1800'
Revetment 530'
Pines River
10,180'
Dikes & Walls
Revere Beach
Backshore LPP
BEACH
REVERE
RIVER
BOSTON HARBOR



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MA

SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

LOCAL PROTECTION
PLANS

OPTION IA

Plate D32

SAUGUS RIVER AND TRIBUTARIES

FLOOD DAMAGE REDUCTION STUDY

LYNN, MALDEN, REVERE AND SAUGUS, MASSACHUSETTS

GEOTECHNICAL

APPENDIX E

Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

JUNE 1989

SAUGUS RIVER AND TRIBUTARIES

FLOOD DAMAGE REDUCTION STUDY

LYNN, MALDEN, REVERE AND SAUGUS, MASSACHUSETTS

GEOTECHNICAL STUDIES

APPENDIX E

TABLE OF CONTENTS

A. PERTINENT DATA*

1. Purpose.

Coastal Flood Damage Reduction

2. Location.

State - Massachusetts

Counties - Suffolk, Essex, Middlesex

Cities - Revere, Saugus, Malden, Lynn

3. Design Flood**

Frequency - Standard Project Northeaster (SPN) except for Point of Pines which is 100-year

Elevation - 12 Feet National Geodetic Vertical Datum (NGVD) except for Point of Pines which is 10.3 feet NGVD and Revere Park dike which is 20 feet NGVD.

4. Revere Park Dike

Type - Earth fill with stone protection

Top elevation - 23 feet NGVD

Freeboard - 3 feet (hydrologic and hydraulic considerations)

- 0 feet (geotechnical considerations)

Maximum height above landside toe - 15 feet

Slopes - Oceanside - 1 vertical to 2.5 horizontal

- Landside - 1 vertical to 2.5 horizontal

Length - 3,420 feet

Top Width - 10 feet

Design wave height - undetermined***

5. Ponding Area Wall

Type - Concrete Gravity

Top elevation - 12 feet NGVD

Freeboard - 1 foot (hydrologic and hydraulic considerations)

- 0 feet (geotechnical considerations)

Maximum height above existing ground - 6 feet

Total length - 500 feet

6. Point of Pines Revetment

Type - Stone

Top elevation - 16 feet NGVD to 16.5 feet NGVD

Freeboard - 5.7 feet to 6.2 feet (hydrologic and hydraulic considerations)

- 0 feet (geotechnical considerations)

Maximum height above landside toe - 5 feet

Slopes - Oceanside - 1 vertical on 3 horizontal

Landside - varies

Total length - 1,550 feet

Top width - 10 feet

Design wave height - 10.4 feet

7. Point of Pines Revetment and Dune

Type - Sand dune over stone revetment

Top elevation - 14 feet NGVD to 16 feet NGVD (dune)

- 14.5 feet NGVD (revetment)

Freeboard - 4.2 feet NGVD to 5.7 feet NGVD (hydologic and hydraulic considerations)

- 0 feet (geotechnical considerations)

Maximum height above landside toe - 7 feet (dune)

- 5 feet (revetment)

Slopes (revetment only) - Oceanside - 1 vertical on 3 horizontal

Landside - 1 vertical on 1 horizontal

Top Width - Varies

- 10 feet (revetment)

Length - 1,600 feet

Design wave height - 10.4 feet

8. <u>Point of Pines Concrete Cap</u>

Type - Concrete

Top elevation - 14 feet NGVD

Freeboard - 2 feet

Height - 1.7 feet

Width - 5 feet

Length - 200 feet

9. <u>Point of Pines Wall</u>

Type - Concrete T-wall

Top elevation - 14 feet NGVD to 15 feet NGVD

Freeboard - 2 feet to 3 feet (hydrologic and hydraulic considerations)

- 0 feet (geotechnical considerations)

Maximum height above landside - 6 feet

Length - 700 feet

10. <u>Saugus River Floodgate - Dike Reaches</u>

Type - Earthfill with stone protection

Top elevation - 18 feet NGVD

Freeboard - 3 feet (hydrologic and hydraulic considerations)

- 3 feet (geotechnical considerations)

Maximum height above landside toe - 29 feet (end of construction)****

Slopes - Oceanside - 1 vertical to 3 horizontal

Landside - 1 vertical to 3 horizontal

Total length - 545 feet

Top width - 16 feet

Design wave height - 2.1 feet

11. <u>Saugus River Floodgate - Navigation Gate</u>

Type - Miter Gate

Width - 100 feet (gate only)

Total width - 148 feet (base)

Gate height - 33 feet

Top elevation - 15 feet NGVD (gate only)

Foundation - End bearing piles (concrete)

12. Saugus River Floodgate - Flushing Gates

Type - Tainter Gates

Number - 10

Gate width (each) - 50 feet

Gate height (gates only) - 14 feet

Total width - 582 feet

Foundation - End bearing piles (concrete)

13. Lynn Dikes

Type - Earth fill with stone protection

Top elevation -15 feet NGVD and 17 feet NGVD

Freeboard - 3 feet and 5 feet (hydrologic and hydraulic considerations)

- 0 feet (geotechnical considerations)

Maximum height above landside toe - 7 feet

Slopes - Oceanside - 1 vertical on 2 horizontal

- Landside - 1 vertical on 2 horizontal

Total length - 4,400 feet

Top width - 12 feet

Design wave heights - 2.1, 2.4, and 3.4 feet

14. Lynn Walls

Types - Steel sheet pile wall, I-wall and Concrete T-wall

Top elevation - 14 feet NGVD and 15 feet NGVD

Freeboard - 2 feet (hydrologic and hydraulic considerations)

- 0 feet (geotechnical considerations)

Maximum height above landside - 14 feet (T-wall)

Lengths - Steel sheet pile - 1,445 feet

- I-wall - 780 feet

- Steel sheet pile cap - 1,100 feet

- T-wall - 100 feet

- Gravity wall - 1,080 feet

15. Clam Flats (Mitigation)

Type - Basin with outlet to Saugus marsh and protective berm

Area - 10 acres (clam bed)

- 2.5 acres (upper slope)

- 0.5 acres (walkway)

- 1.0 acres (protective berm)

Top elevation - 11 feet NGVD (protective berm)

Freeboard - 3 feet (hydrologic and hydraulic considerations)

- 0 feet (geotechnical considerations)

Bottom elevation - 4 feet NGVD (outlet)

Slopes - 1 vertical to 3 horizontal (maximum)

NOTES

*The pertinent data section indicates the information used to develop geotechnical input for the project. The data will be used as a reference for further geotechnical work on the project. It may differ from the main report or other appendices because additional study was performed by other disciplines after completion of the geotechnical input.

**The Hydrologic and Hydraulic Analysis for Tidal Control Appendix should be consulted for more information concerning the design flood.

***The Revere Park dike will only be subjected to small waves. The waves will be generated in the water that collects between the Revere Beach sea wall and the dike. The magnitude of the waves was not determined for the feasibility study.

****The proposed dike will settle up to an estimated three feet after construction of Option 1-Phase 2 which is the preferred option. The options are more fully discussed in paragraph 36.

B. INTRODUCTION

16. Project Description

The primary purpose of the Regional Saugus River Floodgate plan is to provide increased coastal flood protection for more than 5000 residential, commercial and industrial buildings in Saugus, Revere, Malden and Lynn, Massachusetts. The plan would also protect several transportation arteries, increase recreational park land, reduce maintenance costs for over 30 miles of existing shore front and structures (piers, docks, walls, dikes, revetments, moorings, etc) along the coast and the limits of the Saugus and Pines River Estuaries, and protect storage areas in the estuaries. The features of the plan which require significant geotechnical consideration are a 1,275 foot long floodgate structure across the mouth of the Saugus River, 8,905 feet of dikes, walls and gates along the Lynn Harbor, a 3,420 foot long dike behind Revere Beach, 4,050 feet of walls, revetments, dunes at Point of Pines and a 10 acre clam flat basin. The features are shown on Sketch No. E-1.

7. General

Geotechnical engineering studies were performed to further the continued planning of structural features to reduce coastal flooding in Revere, Lynn, Malden and Saugus, Massachusetts. Available explorations and geology information were collected and used to provide a preliminary assessment of the distribution and description of potential foundation materials and conditions for the proposed improvements. The preliminary assessment of foundation materials was used to develop preliminary foundation designs, dike sections, wall sections and construction methods.

Regional floodgate and local protection plans were each evaluated at the 100-year, 500-year and Standard Project Northeaster (SPN) levels of flood protection. A flood proofing plan was evaluated at only the 100-year level of protection. The Regional Saugus River Floodgate plan at the SPN level of design has the highest net economic and social benefits and reduction in flood damages. The cross sections included in this Appendix are for the Regional Floodgate plan at the SPN level of protection except for the Point of Pines area. A previous Point of Pines study dated October 1984 optimized benefits at approximately a 100-year level of protection. Its addition into the Regional plan was too late to develop specific cross sections for this report.

18. Elevations.

All elevations mentioned in this report are in reference to the National Geodetic Vertical Datum (NGVD), which is the mean sea level of 1929. Mean high tide is elevation. 5.0 feet and mean low tide is elevation -4.5 feet.

C. TOPOGRAPHY, GEOLOGY AND SEISMICITY

19. Topography

The project area is located in the Boston Lowland Division (La Forge, 1932) of the Boston Basin. The Boston Lowland is bounded to the north by the Fells Upland, which for the most part, is delineated from the Lowland by an escarpment. The greater part of the Lowland along the coast is less than 50 feet above sea level. Locally, higher areas (up to 175 feet above sea level in the project area) are mainly comprised of drumlins of which there are more than 100 in the Boston Basin, some of which are partially submerged and form many of the higher areas of the Boston Harbor island. The more prominent nearby drumlins are in the southern part of the project area and include Youngs Hill, Fennos Hill, Beachmont, Orient Heights, and Grover Cliff. The low areas are dominated by Revere Beach, a barrier beach which fronts a large salt marsh and the estuary of the Saugus and Pines rivers. Revere Beach is bounded on the south by Roughan's Point, a bouldery headland, and on the north by Point of Pines, a sandy promontory which widens towards its end. The northern limit (Lynn area) of the project area consists mainly of former marsh land now filled and fronted by wood and steel bulkheads and stone revetments, while the southern end is dominated by a timber bulkhead fronted by a narrow beach which is mostly submerged at high tide.

20. Geology.

The subsurface bedrock influences the topography of the project area. The Boston Basin is a structural as well as topographic depression filled by late Paleozoic rocks, chiefly sedimentary, which are younger than the crystalline rocks which rim the basin. The sudden change to a rocky terrain, which marks the northern part of the Basin and the project area, is the hanging wall of the Basin's boundary fault. In the project area this older rocky terrain starts just north of Washington, Walnut and Holyoke Streets in Lynn and just northwest of Lincoln Avenue in Saugus. The bedrock underlying the project area is the Cambridge Argillite, an indurated non-fissile siltstone and mudstone. There are no known surface exposures of the argillite in the project area since the top of this rock is in the range of 60 to 200 feet below the surface. The bedrock-soil interface is thought to be mostly unweathered, although some rock cores from the area show poor recovery which may indicate either a fractured or weathered surface. Elsewhere in the Boston Basin, the Cambridge Argillite is locally altered to clay.

The sediments now overlying the bedrock are ice contact (till), glaciofluvial or marine in origin. Till, most prominently in the form of drumlins, tends to be more stoney than the till of the general drift sheet which is buried in most of the project area. The till is overlain in places by clays of marine or lacustrine origin and/or outwash. A blue clay as well as a yellow clay have been noted in the area borings. The yellow clay may be a weathered variety of the blue clay. The clays are generally overlain by peat of salt marsh origin. The beach deposits are redistributed granular materials from glacial outwash and till. Southward of the project area are several shoreline drumlins which, until earlier this century when sea walls were constructed, had been actively eroding from wave and current action. Roughans Point and Cherry Island Bar are the bouldery, cobbly erosional remains of a drumlin. The sand and gravel fraction of the drumlin tills was redeposited along the beach to the north, while the silts and clays were carried offshore. Additional sands and gravels were also added to the beach from the outwash deposits between Young's Hill and Crescent Beach. Point of Pines owes its wideness to a series of coalesced, recurved spits formed from sands transported northward in longshore current.

21. Seismicity.

The proposed project lies in seismic zone 3 according to the seismic zone map of the United States (USACE, 1983). The "major damage" rating has been assigned due to the concentration of earthquake centers in the Cape Ann area with Modified Mercalli intensities up to VIII.

D. SUBSURFACE INVESTIGATIONS

22. Presentation of Data

Subsurface explorations and laboratory tests were not performed for the current study. Subsurface information was collected from exploration programs executed for other proposed and completed projects that lie in the vicinity of proposed structures. Locations of the subsurface explorations collected are shown on Sketch Nos. E-2 to E-5. Typical soil profiles of the subsurface explorations are presented on Sketch Nos. E-6 to E-9.

23. Subsurface Explorations

The logs of eleven test boring programs and two test pit programs which were performed in the vicinity of the proposed project, were collected. Borings were typically advanced using standard wash methods. Standard penetration tests and split spoon samples were generally taken at 5-foot intervals. The test boring depths varied from 23 feet to 170 feet. Apparent bedrock was encountered in nine of the test borings. The test pits were typically excavated to 10 feet of depth unless refusal was encountered or cave-in occurred. Table E-1 summarizes the subsurface exploration programs.

24. Laboratory Soil Testing

Laboratory soil testing of the foundation and proposed embankment materials was not executed for the current study. Laboratory testing results from four of the exploration programs performed in the general vicinity of the project were collected. It appears that the tests were generally performed in accordance with current Corps laboratory soil test procedures for Civil Works projects. The test results are presented in Table E-2.

25. Future Explorations

At least two exploration and laboratory testing programs will be required to complete design of the subject project. The two programs will be performed as part of the general and feature design memoranda work for the project. Additional exploration work, if required, will be performed during preparation of the project's plans and specifications.

E. SUBSURFACE CONDITIONS

26. General.

The nature of subsurface conditions was studied using geologic maps, observations from site visits and exploration logs. A typical soil profile was developed for the Saugus River Floodgate structure, the Lynn walls and dikes, the Revere Park dike, and the Point of Pines, dunes, revetments and walls. Each typical soil profile shows average boundary elevations for the soil strata encountered in explorations performed in the vicinity of the major project features. It also shows average Standard Penetration Test (SPT) values for each stratum encountered. Boundary elevations and SPT values may vary considerably between explorations. The typical soil profiles which were developed are presented in Sketch Nos. E-6 to E-9.

27. Soil Stratum Descriptions.

Eight major soil types were encountered in the explorations. They are shown on the typical soil profiles and are more fully described below.

Fill. Surficial fill was encountered in the Revere Park dike area and the northern portion of the Lynn dikes and walls area. The fill thickness varied from 0 feet to 22 feet in the Park dike area and 0 feet to 30 feet in the Lynn dikes and walls area where it was fully penetrated. Brick fragments, organic silt and clay, loam, cobbles, ashes, wood cinders, concrete, glass, metal, boulders and asphalt were noted in the descriptions of the fill. The highest concentrations of the deleterious materials appeared to be in the top 5 feet of the fill in the Park dike area. Standard penetration test results indicates that the surficial fill is very loose to very dense.

Granular Soils. Granular soils were found at the surface at Point of Pines, Saugus River Floodgate, and approximately the south one-half of the Lynn walls and dikes areas. They were also found below the surficial fill in the Revere Park dike and approximately the north one-half of Lynn walls and dikes area. The granular soils were usually brown, fine to medium sand with 0 to 20 percent gravel and 0 to 20 percent silt. Higher gravel contents (up to 60 percent by weight) were noted in some of the samples taken near the surface in the Revere Park dike and Point of Pines areas. Higher silt contents (up to 50 percent by weight) were noted near the surface of the granular soils in approximately the south one-half of the Lynn dikes and walls area. Thin peat layers (typically 1/8-inch thick) were found near the bottom of the granular soils in the Point of Pines area. Silt and clay layers up to 1 inch thick were found in the granular soils in approximately the north one-half of the Lynn dikes and walls area. The granular soils are very loose to very dense based on standard penetration test results.

Organics. A thin layer of organic soils was found in approximately one-fourth of the borings except for the Point of Pines area. The organic soils are generally dark brown to black organic silts and peats. They varied in thickness from 1 foot to 10 feet except for boring H-2 (Lynn dikes and walls area) where approximately 26 feet of organics were encountered. The results of standard penetration tests indicate that the organic soils are very soft to stiff.

Yellow Clay. Yellow silty clay was noted in approximately one-third of the borings in the Revere Park dike and Saugus River Floodgate areas. The yellow silty clay varied in thickness from 4 feet to 20 feet in the explorations that it was observed. Standard penetration tests results indicate that the yellow silty clay is medium stiff to hard. The liquid limit varied from 40 to 43 and the plastic limit varied from 18 to 19 in three Atterberg limit tests performed on the yellow silty clay.

Gray Silty Clay. A compressible gray silty clay (Boston Blue Clay) layer was the predominant soil stratum encountered in the study area. The stratum thickness varied from 14.5 feet to 98.5 feet in the explorations where it was completely penetrated. Twenty-three Atterberg limit tests executed on the gray silty clay produced liquid limits from 31 to 53 and plastic limits from 16 to 29. The gray silty clay is very soft to very stiff based on standard penetration test results.

Gray Sandy Clay. A gray sandy clay was found below the gray silty clay in the south one-half of the Lynn dikes and walls area only. The sandy clay varied from 5 feet to 27 feet in thickness. The descriptions of the sandy clay indicated that it was slightly to moderately plastic. It is very stiff to hard based on standard penetration test except for a 15 foot lens in exploration F-324 (Lynn dikes and walls area) where is was very soft.

Sand and Gravel. Sand and gravel with trace to little silt and clay content was sampled below the clay and above bedrock in the study area except for the Point of Pines area where the explorations were not deep enough to do so. The descriptions of the sand and gravel generally indicated that the sand content was slightly greater than the gravel content. Sand as well as gravel contents up to almost 100 percent were noted in a couple of the descriptions. The sand and gravel layer was from 5 feet to 41 feet thick where it was fully penetrated in the explorations. Standard penetration test results from 8 to 396 indicate that the sand and gravel density varies from loose to very dense. Standard penetration test results greater than 100 probably indicate the presence of cobbles and boulders in the sand and gravel.

Argillite. The deepest material sampled was argillite bedrock. The argillite was described as slightly weathered, moderately hard, fine grained and thin bedded in the sample descriptions.

28. Groundwater.

Groundwater was generally observed between the mean high tide level (elev. 5.0 feet) and the mean low tide level (elev. -4.5 feet) in the explorations. Many of the logs indicated that the groundwater fluctuated with the tide level. It should be noted that fluctuations in the groundwater level may occur due to variations in tide, rainfall, snow, temperature, ice, wind, or other factors which differ from the conditions present at the time the observations were made.

F. DESIGN AND CONSTRUCTION

29. General.

Proposed sections for the project are shown on Sketch Nos. E-10 to E-17. The proposed sections for the Saugus River Floodgate and the Lynn dikes and walls area were specifically developed for the subject feasibility study. The proposed embankment section for the Revere Park dike area was developed for a reconnaissance report on the Revere Beach Backshore. Aesthetic and small physical modifications were made to the Revere Park dike section for the subject feasibility study. The revetment, dune, and wall sections for the Point of Pines area were developed for a Detailed Project Report on the Point of Pines area. Modifications were not made to the Point of Pines sections for the current study because the Point of Pines area was added to the study at too late a date.

30. Design Criteria.

The principles and procedures discussed in USACE Engineering Manual EM 1110-2-1913, "Design and Construction of Levees", were used to develop dike sections for the proposed project. The proposed revetments were developed from the principles and procedures outlined in the USACE Coastal Engineering Research Center, "1984 Shore Protection Manual". Layer thicknesses and stone sizes for the proposed stone protection on the dikes and revetments were calculated using procedures in USACE Engineering Manual EM 1110-2-1601, "Hydraulic Design of Flood Control Channels", USACE Engineering Technical Letter, ETL 1110-2-120, "Additional Guidance for Rip Channel Protection" and the USACE Coastal Engineering Research Center, "1984 Shore Protection Manual". Preliminary designs for the proposed cofferdams at the Saugus River Floodgate were developed from guidance in USACE Technical Report, ITL-87-5, "Theoretical Manual for Design of Cellular Sheet Pile Structures" and Department of the Navy Design Manual, NAVFAC DM-7.2, "Foundations and Earth Structures".

31. Characteristics of Embankment Materials

Some of the materials from the required stripping and excavation operations will be suitable for use in the construction of the dikes and revetments as well as backfill for the walls and Saugus River Floodgate structure. The suitable materials from the excavation and stripping operations will be used to the extent practicable. The contractor will furnish all embankment materials other than those available from the required excavation and stripping operations, due to the high cost of developing Government-furnished borrow areas and difficulty involved in acquiring the land for borrow areas. The proposed embankment materials are described below.

Random Fill. Random fill will be a friable, granular, low plasticity unprocessed soil. The amount of soil particles passing the No. 200 sieve will be less than 35 percent of the random fill's dry unit weight. Random fill shall be free of stumps, trash, debris, cinders, ashes, topsoil, sod, roots, organic soils, boulders and other deleterious materials.

Impervious Fill. Impervious fill will be a well graded, natural unprocessed material which contains sand, silt and clay sized particles. The material will not contain organic matter, vegetation, sod, roots, debris, frozen soil or boulders. Impervious fill will be well graded within the following limits:

Sieve Size (U. S. Standard)	Percent Passing by Dry Weight
6-inch	100
3-inch	90-100
No. 4	60-95
No. 4	35-75
No. 200	20-50

Gravel Fill and Bedding. Gravel fill and bedding materials will be a natural material consisting of sand, gravel and crushed stone particles. The particles will be tough, durable and angular. Gravel fill and bedding will be free from thin, flat and elongated particles, organic matter, friable particles, loam, clay and other deleterious materials. Gravel fill and bedding shall be well graded within the following limits:

Sieve Size (U. S. Standard)	Percent Passing By Dry Weight
3-inch	100
1/2-inch	50-85
No. 4	40-75
No. 50	8-28
No. 200	0-8

Topsoil. Topsoil will be a fertile, friable mixture of sand, silt and clay particles. It shall be free of roots, stumps, cobbles, boulders, gravel larger than one inch in diameter, clay lumps, weeds, brush and trash. It will have demonstrated that it is capable of supporting vegetative growth before it is stripped.

Sand. Sand will consist of clean, inert grains of durable rock smaller than 1/4 inch in diameter. It will be free from loam, clay, debris, gravel, cobbles, boulders and other deleterious materials. The amount of particles passing the No. 200 sieve will be less than 10 percent of the sand's dry unit weight.

Granular Fill. Granular fill will be a well graded, natural unprocessed material which contains primarily sand and gravel particles. The individual particles will be hard durable stone and sand free from clay, trash, debris, snow, ice and any other deleterious materials. Granular fill will be well graded within the following limits:

Sieve Size (U. S. Standard)	Percent Passing By Dry Weight
6-inch	100
No. 10	30-95
No. 40	10-70
No. 200	0-15

Silty Sand. Silty sand will be a well graded, natural material which contains mainly sand and silt particles. The material will not contain organic matter, vegetation, sod, roots, debris frozen soil or boulders. The amount of particles passing the No. 200 sieve will be more than 20 percent and less than 45 percent of the silty sand's dry unit weight.

Stone Bedding. Stone bedding will consist of hard, durable, angular and sound quarried rock fragments. The rock fragments will have a unit weight of not less than 162 pounds per cubic foot based on the saturated surface dry specific gravity. Stone bedding shall be well graded between 0 pounds and 50 pounds.

Stone Protection. Stone protection materials will consist of hard, durable, angular, irregular, and sound quarried rock fragments. Each stone will have a density of not less than 162 pounds per cubic foot based on the saturated surface dry specific gravity. Stones in the material will not have long dimensions which exceed 3 time their short dimension. The proposed ranges of stone weight (in pounds) for the subject project are listed below.

Class	Maximum Weight	Mean Weight	Minimum Weight
I	3500	900	100
II	1500	400	50
III	350	90	10
IV	120	25	2

32. Sources of Materials.

Producers of earth, sand, gravel and stone materials were contacted November 1988 to identify sources which could provide the large quantities required for the proposed project. All of the required materials can be supplied by producers located within a 50 mile radius of the project site. Table E-3 lists possible producers and the materials that they could supply.

33. Design Values.

Laboratory tests were not performed on the foundation materials or the proposed embankment materials for the current study. Design values were estimated based on laboratory and exploration log data collected from other projects in the immediate vicinity, data from similar projects in the Boston Metropolitan area, and experience with similar materials. The estimated design values are shown on Table E-4.

34. Seepage Control.

The design hydrostatic head for the proposed dikes and walls is the difference between the SPN flood level (El. 12 feet) on the oceanside and a water level at the lowest point along the ground surface (El. 6 feet) on the landside. The design hydrostatic head at the Saugus River Floodgate structure is the difference between the SPN flood level (El. 12 feet) on the oceanside and the water level at the lowest estimated elevation of closure (El. 2 feet) on the landside. The duration of the design hydrostatic head in each case is an estimated two hours. Project features will experience 50 percent or more of the design hydrostatic heads up to seven hours. The relatively small and short duration design hydrostatic heads predicted for the subject project should not cause serious seepage problems. Potential seepage will be controlled by semi-impervious core and foundation materials, and the length of the seepage path. A landside toe drain does not appear to be needed at this time.

35. Embankment Stability.

Stability analyses of the Revere Park dike, Point of Pines, and Lynn embankments were not judged to be necessary for the current study. A stability analysis was performed on the Saugus River Floodgate section shown on Sketch Nos. E-12 to E-14 using non-circular failure surfaces and the UTEXAS2 slope stability program. The design unit weights and shear strengths used in the program are shown on Table E-4. A minimum factor of safety of 1.3 was calculated. The results indicate that the proposed section is safe from failure for the conditions analyzed.

36. Settlement.

The silty clay and organic foundation soils which are described in the exploration logs and shown on the typical profiles (Sketch Nos. E-6 to E-9) are highly compressible. Preliminary settlement estimates based on assumed compression indices indicate that up to six feet of total settlement could occur under the embankment portion of the proposed Saugus River Floodgate. It was also estimated that proposed dikes, revetments, utilities and walls which are not supported by end bearing piles could settle up to two feet. The settlement will continue after the project is completed but will occur at slower and slower rates.

All project features will be designed to withstand the foreseeable structural and flood problems that might occur due to settlement. Two possible schemes are proposed to deal with the six feet of estimated settlement at the Saugus River Floodgate embankment. They are shown on Sketch Nos. E-12 to E-14. The preferred scheme (Sketch Nos. E-12 and E-13) would involve stage construction. The embankment would be constructed to approximately El. 10 feet and allowed to settle (approximately three feet) for 6 to 12 months. Then the embankment would be overbuilt to El 18 feet to accommodate the approximately three feet of settlement which could occur during the next 100 years. A second scheme (Sketch No. E-14) in which the embankment would be overbuilt to El. 21 feet and allowed to settle approximately six feet during the next 100 years is also a possibility. The first scheme is preferred because cracks and holes which develop in the embankment during the initial 6 to 12 month settlement period could be filled. Vertical drains will be used with either scheme to expedite the settlement so that 90 percent of the total estimated settlement should occur within 12 months after completion of the overbuilt embankments. Surcharging, foundation modification, stage construction and eliminating the vertical drains will be studied as methods to reduce the detrimental effects from the estimated settlement. The risk of each method will be considered, and if the risks are unacceptable, a wall supported by end bearing piles will be required.

The proposed dikes, revetments, utilities and walls which are not supported by end bearing piles have not been designed to withstand settlement due to time and cost limitations. Money has been included in the cost estimate contingencies for modifications which might have to be made to these structures. The problem will be studied in more detail during the next study stage.

Settlement of dikes and embankments adjacent to pile supported structures is a concern. The settlement of the dikes and embankments will induce downdrag forces on the piles and subsidence below the structures. The magnitude of the downdrag forces on and subsidence below the proposed and existing pile supported structures has not been determined due to time and cost limitations for this study. The use of sheet pile cutoff walls, more pile supported structures and changes in the construction sequence or alignment may be required to alleviate these problems. They will be studied in more detail during the next study stage.

37. Placement and Compaction.

Compacted fill materials will be spread with bulldozers or other approved equipment in loose layers of 8 inches in non-restricted areas and 4 inches in restricted areas. Each layer will be compacted to 95 percent of its maximum dry unit weight as determined by modified proctor test ASTM D-1557. Heavy tractors and vibratory rollers will not be allowed in restricted areas. Restricted areas will be defined as follows:

a. Areas within 3 feet, measured horizontally, of the outer surface of utility pipes, appurtenant structures, small conduits and similar items until the fill has been constructed to a level 12 inches above the top of a metal pipe or 24 inches above the level of any other pipe or item.

b. Areas over the top of footings until the concrete has been covered with 9 inches of fill material.

c. Areas within 3 feet, measured horizontally, of the outer structure of retaining walls.

d. Areas of a compacted fill zone at any elevation where compaction of the fill material can not be accomplished with tractors due to space limitations.

38. Slope Protection.

Coastal and hydraulic engineering analysis of wave conditions for the geotechnical design of project features except for the Revere Park dike indicates that maximum wave heights which will occur during a SPN storm will vary from 2.1 feet to 10.4 feet. It was assumed only small waves (less than 2 foot) would impact the Revere Park dike. They would be generated in the ponded water that overtopped the existing Revere Beach seawall. The 10.4 foot maximum wave height calculated for the Point of Pines Detailed Project Report appears to be over conservative based on recent WES studies and will be re-evaluated during the next study stage.

Stone layer thicknesses and stone sizes were calculated using the maximum wave heights. Proposed stone protection sections are shown on Sketch Nos. E-10 to E-15. The stone sizes required to construct the minimum exposed layer thickness (2 feet in Lynn Dikes and Walls area) will be large enough to be considered "vandal proof". Proposed classes and weight ranges for the stone protection are listed in Section 31.

39. Pile Foundations.

The navigation gate and flushing gates for the Saugus River Floodgate will be concrete and steel structures which will not withstand a large amount of differential settlement. The foundation materials for the proposed gates are highly compressible. Deep piles which extend into the argillite bedrock will be needed to properly support the gates. Prestressed concrete, steel pipe and steel H piles were considered. It appears that the prestressed concrete piles will be most economical based on discussions with local pile driving contractors. It was assumed that the prestressed concrete piles will penetrate the argillite bedrock approximately 10 feet.

40. Environmental.

The proposed project will not adversely impact the geology, topography or soils in the project area. Estimated settlement of the foundation materials under the proposed earth embankments will increase from 0 to 2 feet to 0 to 6 feet. Erosion of surficial soils in the project vicinity should decrease if the project is implemented.

41. Access.

Access is good along the proposed project alignment. Bituminous concrete roads run adjacent to the Park dike, Point of Pines and south end of the Saugus River Floodgate areas. The north end of the Saugus River

Floodgate and the Lynn Dikes and Walls areas are typically flat filled areas. Gravel haul roads may be needed in these areas to support heavy equipment during wet periods. Many commercial marinas are within 5 miles of the proposed site which could be used to launch and support work boats and barges.

42. Pipelines.

Storm drain pipelines cross the proposed dike and revetment alignments at many locations. The storm drains will be combined and relocated to the extend practicable. Flexible storm drain pipes or oversized annular sleeves will be used where the storm drains must cross dikes and revetments to reduce possible damage to the pipes from differential settlement. Flapgates or similar structures map may be used at the end of each storm drain pipe to prevent inflow of water.

43. Accelerated Sea Level Rise.

Accelerated sea level rise would increase the potential that project features are overtopped. Overtopping could damage project features and flood areas on the landside of project features. Sea level rise at the historical rate of one foot per one hundred years is not expected to cause significant damage to project features nor major flood problems.

Accelerated sea level rise at the maximum estimated rate of four feet per one hundred years would cause significant damage to and some flooding behind all of the earth structures along the project alignment. The damage to earth structures could be reduced by providing stone protection on the backside of the Revere Park dike and Lynn dikes which are the only earth structures along the alignment which are not designed for significant overtopping. Potential flood damage could be reduced by increasing the height of all structures along the project alignment four feet. The costs for protecting the Revere Park dike and Lynn dikes against overtopping are relatively insignificant. The real estate and material costs for raising all the structures to reduce flooding are high.

44. Cofferdams.

Various schemes using combinations of cellular cofferdams, ring girder cofferdams, and braced excavations were considered to provide a dry construction area for the proposed gates. A scheme using a ring girder cofferdam to construct the navigation gate and braced excavations to construct the flushing gates is preliminarily judged to be the most economical. It does not appear that installation of steel sheet piles required for the cofferdams will be a problem. The steel sheet piles will be pulled and reused to the extent practicable for the Lynn walls. Further study is necessary to determine the most economical cofferdam scheme.

45. Dredging.

Dredging of the Saugus River channel will be required to excavate for the foundation and base of the proposed Saugus River Floodgate, provide flow channels to the gates, and to provide an alternate navigation channel during construction of the navigation gate. Borings in the vicinity of the proposed areas to be dredged show that the materials to be dredged could vary in size from a silty clay to a fine sand. The materials will be used on other project features to the extent practicable. The excess material will be disposed of at an open ocean disposal site.

46. Construction Sequence.

The construction sequence for the proposed project is described in Appendix A. It is arranged so that environmental impacts to the Saugus Marsh should not be significant and navigation through the channel will be maintained without compromising the design of the project. Further study is recommended after the WES Saugus River model study and preliminary borings to re-evaluate the sequence and add stone protection in areas where channel velocities are increased significantly during construction.

47. I-95 Embankment.

It appears that the I-95 embankment presently retards flood levels west of the embankment for most storms. Recent mining of the embankment has raised the question: How much of the embankment can be removed without sacrificing its flood retention capabilities? Cursory hydraulic and hydrologic tide gage measurements show approximately two feet of head is retained across the embankment during major flood events without the Regional Saugus River Floodgate plan. The estimated flood water elevation east of the embankment during major storms is approximately 2.5 feet lower with the Saugus River Floodgate regional plan than without. Preliminary seepage and stability studies were performed to develop the minimum safe section (maximum allowable cut) during major flood events. Sketch No. E-16 shows the maximum allowable cuts for the with and without Regional Saugus River Floodgate plan conditions. The top allowable cut elevation (El. 11 feet with and El. 13.5 without the Regional Saugus River Floodgate plan conditions) is approximately 3 feet above (freeboard) the estimated stillwater level during major flood events east of the embankment. The bottom allowable cut elevation was set at El. 5 feet because El. 5 feet matches existing grades, and it is feared that deeper cutting operations would remove material that is too salty or contains too high an organic content for reuse.

48. Mitigation.

Construction of the Regional Saugus River Floodgate plan will destroy approximately 10 acres of clam flats. Similar flats will be constructed and developed along the north side of the I-95 embankment approximately 1000 feet east of Copeland Circle and immediately south of the Seaplane Basin. The I-95 embankment will be cut to El. 9 feet by the State of Massachusetts and local contractors for other projects prior to plan mitigation. Then, a 13 acre basin (include approximately 10 acres of clam flats) will be cut into the embankment. A sketch through the center of the proposed basin is shown on Sketch No. E-17. The buffer zone will be used as an access road to the mitigation area. The protective berm (El. 11 feet), which is designed with 3 feet of freeboard, will be constructed to retard flood levels west of the I-95 embankment after removal of the outer berm (El. 15 feet). The flood retention capabilities of the I-95 embankment are more fully discussed in the preceding paragraph. The alternate mitigation area will be used if the proposed mitigation area is unacceptable.

Approximately 186,000 cubic yards (cy) of granular materials and 4,000 cy of organic materials will be excavated for the basin. The granular materials and peat will be excavated with a backhoe or dragline and transported by truck to designated disposal areas. It appears that 76,000 cy of the granular materials excavated (El. 9 feet to El. 5 feet) should be relatively clean. The clean granular materials will be used for the Revere Park dike's random fill section (56,000 cy) or sold for general use from a stockpile located east of the basin. It is assumed that the remaining 110,000 cy of granular materials excavated (El. 5 feet to El. -4 feet) will have a high salt content because they are presently situated in the tidal zone. They will be used for dumped granular fill and random fill sections of the Lynn dikes and walls (72,000 cy) and Point of Pines Beach replacement (6,000 to 8,000 cy). The remaining high salt content material could be used for Revere Beach and Point of Pines beach maintenance and road sanding. It will be stored in a berm around the basin. The organic materials will be trucked off site to a disposal area.

49. Ponding Area Wall.

The ponding area will require approximately 500 feet of concrete gravity wall. The maximum height of the wall above grade will be 6 feet. It does not appear that there will be any major geotechnical concerns that would hamper the design and construction of the wall at this time.

TABLE E-1

SUMMARY OF SUBSURFACE EXPLORATION PROGRAMS

SYMBOL	TYPE	DATE	NUMBER	DEPTH(S) (Feet)	CLIENT	CONTRACTOR	LOGS BY
A	Test Pits	1977	8	2-10	Fay, Spofford & Thorndike, Inc.	Soil Explor. Co.	Soil Explor. Co.
B	Borings	1977	9	35-83	Fay, Spofford & Thorndike, Inc.	Soil Explor. Co.	Soil Explor. Co.
C	Borings	1977	5	76-90	Haley & Aldrich	Al Shiner Test Boring, Inc.	Al Shiner Test Boring, Inc.
D	Borings	1973	2	105-112	Metcalf & Eddy Engineers	C.L. Guild Drilling & Boring Co.	C.L. Guild Drilling & Boring Co.
E	Borings	1962	8	45-60	Metro. Dist. Com.	-	-
F	Borings	-	4	108-170	New England Power Co.	-	Stone & Webster Eng.
G	Borings	-	1	18	New England Power Co.	-	Stone & Webster Eng.
H	Borings	1984	5	23-92	Bay Marine	Carr-Dee Corp.	Goldberg-Zoino & & Associates
I	Borings	1987	3	52	Haley & Aldrich	Carr-Dee Corp.	Carr-Dee Corp
J	Borings	1973	4	30-60	Metro. Dist. Com.	D.L. Jones Sub. Invest. Inc.	D.L. Jones Sub. Invest. Inc.
K	Borings	193[illegible]	31	39-111	Metro. Dist. Com.	-	J.R.Worcester & Co.
L	Borings	1982	8	30	USACE	Briggs Eng. & Test.	Briggs Eng. & Test.
M	Test Pits	1985	13	4-10	USACE	Atlantic Test. Labs	Atlantic Test. Labs

Notes: 1. The exploration locations are shown on Sketch Nos. E-3 to E-5.

2. Typical soil profiles of the explorations are shown on Sketch Nos. E-6 to E-9.

TABLE E-2

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS: GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS: LL	PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT: TOTAL	-NO4	NAT. DRY DENSITY LBS/CUFT: TOTAL	-NO4	SHEAR STRENGTH TESTS: Torvane or Type Test	σ_c or $\bar{\sigma}_c$ or σ psf	Failure Criteria	$\sigma_1 - \sigma_3$ or T psf	Strain %
A-2		1	2	SP	19	78	3	0.18				14.1								
A-2		2	6	GP	53	44	3	0.23				8.4								
A-4		1	2	SW	72	17	1	0.70				25.7								
A-4		2	7	SP	9	91	2	0.10				22.5								
A-5		1	8	SP	0	97	3	0.10				23.0								
A-7		1	3	SM	43	48	9	0.08				24.0								
B-7		7	33-35	CL	0	6	94		43.0	18.1		27.2								
B-9		9	35-37	CL	0	1	99		49.0	22.0		40.4								
B-9		18	78-80		52	33	15													
B-10		6	29-31	CL	0	24	76		30.7	15.8		26.8								
B-12		7	22-24	CL	0	7	93		40.0	18.0		22.0								
B-13		5	20-22	CL	0	3	97		40.2	19.1		26.2								
B-13		7	33-35	CL	0	7	93		42.8	18.2		31.2								
H-1	9.2	1	50.1									44.0				TV=0.25 tsf				
H-1	9.2	1	50.6									43.7				TV=0.39 tsf				
H-1	9.2	1	50.7-51.1	CL					43.0	22.0		38.9		80.9		UU	$\bar{\sigma}_c$= 5500	$\sigma_1 - \sigma_3$ MAX	1650	10.0
H-1	9.2	1	51.1									41.3				TV=0.38 tsf				

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TABLE E-2 (CONTINUED)

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	MECHANICAL ANALYSIS SAND %	MECHANICAL ANALYSIS FINES %	MECHANICAL ANALYSIS D_{10} mm.	ATT. LIMITS LL	ATT. LIMITS PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	NAT. WATER CONTENT % DRY WT -NO4	NAT. DRY DENSITY LBS/CUFT TOTAL	NAT. DRY DENSITY LBS/CUFT -NO4	SHEAR STRENGTH TESTS Torvane or Type Test	SHEAR STRENGTH TESTS σ_c or $\bar{\sigma}_c$ or σ psf	SHEAR STRENGTH TESTS Failure Criteria	SHEAR STRENGTH TESTS $\sigma_1 - \sigma_3$ or T psf	SHEAR STRENGTH TESTS Strain %
H-1	9.2	2	65.2									49.0				TV=0.22 tsf				
H-1	9.2	2	65.7									44.0				TV=0.25 tsf				
H-1	9.2	2	65.8-66.2	CL					49	24		49.5		70.8		UU	σ_3= 7200	$\sigma_1 - \sigma_3$ MAX	1480	3.0
H-1	9.2	2	66.2									47.1				TV=0.22 tsf				
H-1	9.2	2	66.7									37.6				TV=0.23 tsf				
H-1	9.2	3	90.2									57.0				TV=0.25 tsf				
H-1	9.2	3	90.6									46.3				TV=0.24 tsf				
H-1	9.2	3	90.7-91.1	MH					53	24		48.2		72.4		UU	σ_3= 9995	$\sigma_1 - \sigma_3$ MAX	1452	5.0
H-1	9.2	3	91.1									46.9				TV=0.20 tsf				
H-1	9.2	3	91.6									42.9				TV=0.26 tsf				
H-2	9.7	1	45.2-45.3									44.5				TV=0.27 tsf				
H-2	9.7	1	45.7									39.2				TV=0.26 tsf				
H-2	9.7	1	46.2									39.5				TV=0.28 tsf				
H-2	9.7	2	60.2									39.8				TV=0.25 tsf				
H-2	9.7	2	60.6									41.4				TV=0.21 tsf				
H-2	9.7	2	60.7-60.1	CL					49	22		50.7		70.9		UU	σ_3= 6700	$\sigma_1 - \sigma_3$ MAX	1171	5.0
H-2	9.7	2	61.1									54.9				TV=0.20 tsf				

TABLE E-2 (CONTINUED)

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS				ATT. LIMITS		SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT		NAT. DRY DENSITY LBS/CUFT		SHEAR STRENGTH TESTS				
					GRAVEL %	SAND %	FINES %	D_{10} mm.	LL	PL		TOTAL	-NO4	TOTAL	-NO4	Torvane or Type Test	σ_c or $\bar{\sigma}_c$ or σ psf	Failure Criteria	$\sigma_1 - \sigma_3$ or τ psf	Strain %
H-2	9.7	3	80.2									38.3				TV=0.19 tsf				
H-2	9.7	3	80.7									47.7				TV=0.19 tsf				
H-2	9.7	3	80.7-81.1	CH					56	29		37.0		77.6		UU	σ_c= 8900	$\sigma_1 - \sigma_3$ MAX	1490	4.5
H-2	9.7	3	81.1									49.6				TV=0.20 tsf				
H-2	9.7	3	81.6									50.7				TV=0.20 tsf				
H-4	9.7	1	25.6									30.7				TV=0.20 tsf				
H-4	9.7	1	25.7-26.1	CL					38	18		35.4		84.7		UU	σ_c= 2895	$\sigma_1 - \sigma_3$ MAX	1517	4.5
H-4	9.7	1	26.1									43.2				TV=0.25 tsf				
H-4	9.7	1	26.6									44.3				TV=0.23 tsf				
H-4	9.7	2	70.8									53.5				TV=0.10 tsf				
H-4	9.7	2	71.2									39.3				TV=0.25 tsf				
H-4	9.7	2	71.3-71.7						52	22		49.8		70.6		UU	σ_c= 7790	$\sigma_1 - \sigma_3$ MAX	1330	6.0
L-1	5.5	5	20-25	CL					44	24	2.75	26.0								
L-1	5.5	6	25-30	CL-CH					50	24	2.78	31.5								
L-2	8.0	5A	23.5-25	CL					43	22	2.78	26.3								
L-2	8.0	6	25-30	CL					40	21	2.69	24.8								
L-3	6.2	6	25-30	CL					49	24	2.71	36.7								

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TABLE E-2 (CONTINUED)

SOIL TESTS RESULTS

EXPL. NO	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS				ATT. LIMITS		SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT		NAT. DRY DENSITY LBS/CUFT		SHEAR STRENGTH TESTS				
					GRAVEL %	SAND %	FINES %	D_{10} mm.	LL	PL		TOTAL	-NO4	TOTAL	-NO4	Torvane or Type Test	σ_c or $\overline{\sigma}_c$ or σ psf	Failure Criteria	$\sigma_1 - \sigma_3$ or T psf	Strain %
L-4	3.2	4A	18.5-20	CL					47	24	2.74	30.8								
L-4	3.2	5	20-25	CL					49	24	2.77	31.6								
L-4	3.2	6	25-30	CH					51	25	2.76	38.0								
L-5	3.0	4A	18-20								2.70									
L-5	3.0	5	20-25	CH					51	24	2.77	33.7								
L-5	3.0	6	25-30	CH					53	25	2.72	36.9								
L-7	6.5	5A	22.8-25								2.79									
L-5	6.5	6	25-30	CL					49	24	2.73	38.9								
L-8	2.8	5	25-30	CL					53	24	2.73	39.3								
L-8	2.8	5	25-30	CL					47	24										
M-1	7.4		2.5-3.5	SP	18	82	0	0.17												
M-3	5.1		2.0-3.5	GP	59	41	0	0.22												
M-6	0.2		1.8-8.0	SP-SM	8	85	7	0.08												
M-11	0.1		7.0-10.0	SM	0	61	39	0.04												

TABLE E-3

SOURCES OF MATERIALS

PRODUCER	IMPERVIOUS FILL	BANK RUN GRAVEL	TOPSOIL	SAND	GRANULAR FILL	SILTY SAND	STONE BEDDING	STONE PROTECTION
Torromeo Trucking Methuen, MA (1)	X	X	X			X	X	X
Newmarket S&G Newmarket, NH	X	X	X		X		X	
Lynn Sand & Stone Swampscott, MA				X	X		X	X
New England Stone Providence, RI (2)								X
Iafolla Industries Portsmouth, NH (3)		X		X	X		X	X
Nashua River Land Co. Nashua, NH (4)	X	X		X				
Georgetown S&G Georgetown, MA	X	X		X				
Keating Materials Dracut, MA								X
George Brox Dracut, MA								X
Beard Trucking Epping, NH	X	X			X			
O'Donnel S&G Kingston, MA	X	X			X			X (5)
Southeastern S&G Bridgewater, MA (6)				X			X	
KMF Corporation East Kingston, NH	X	X				X		X

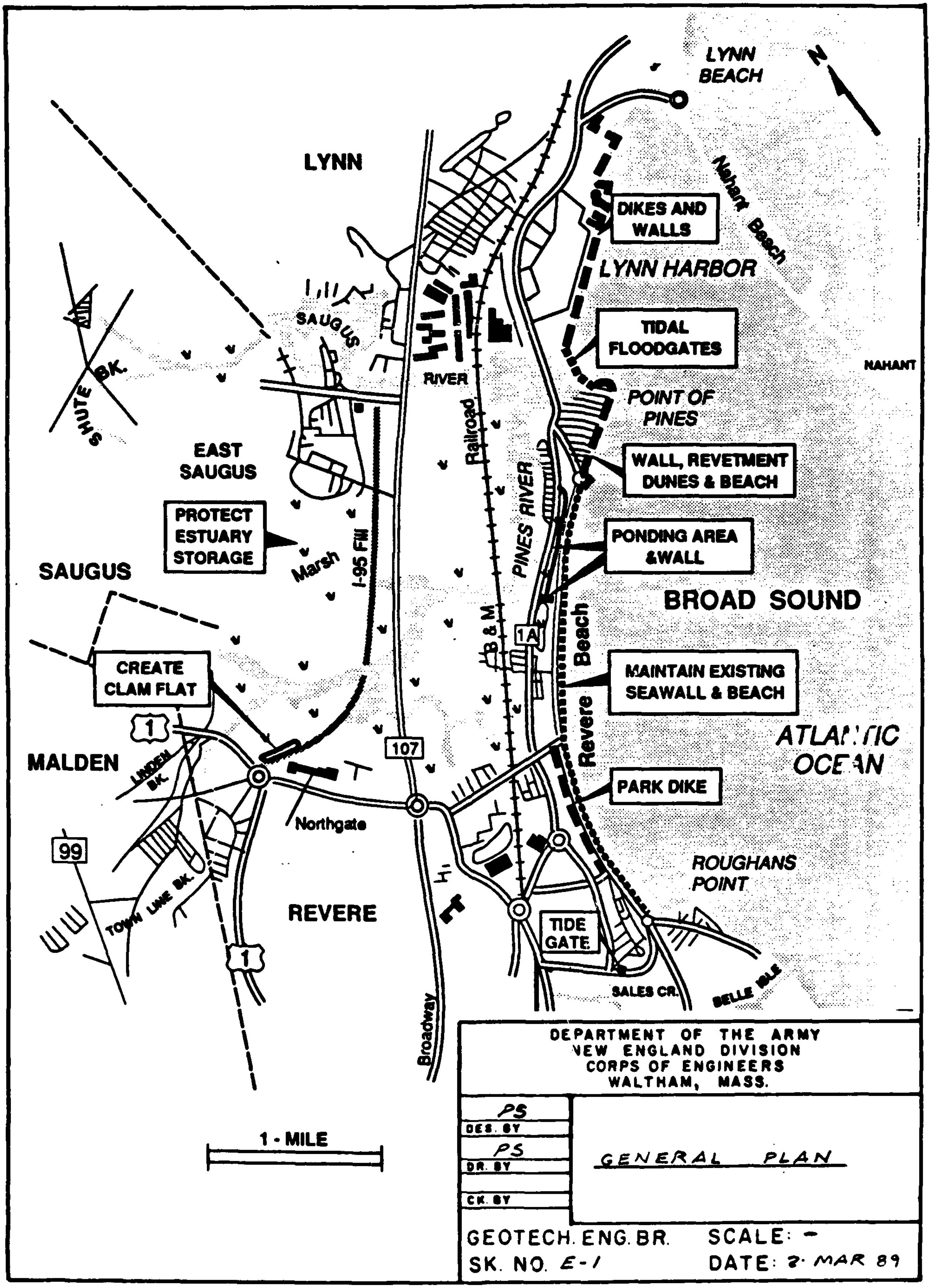
Notes:
1. Pit near Dover, NH
2. Quarry at Crotch Island (off Stonington, ME)
3. Non-stone products shipped from Madbury, NH
4. Several pits in southern NH
5. Sorted at quarry
6. Pit at Plympton, MA

TABLE E-4

ESTIMATED DESIGN VALUES

MATERIAL	LOCATION	SATURATED UNIT WEIGHT (LBS/CF)	STRENGTH c(lbs/sf)	STRENGTH 0 (Degrees)	PERMABILITY (cm/s)
Fill	Foundation	130	0	28	?
Organics	Foundation	90	300	-	$< 10^{-6}$
Granular Soils	Foundation	130	0	25	10^{-3} to 10^{-2}
Yellow Clay	Foundation	125	1000	-	$< 10^{-7}$
Gray Silty Clay	Foundation	125	600	-	$< 10^{-7}$
Gray Sandy Clay	Foundation	130	2000	-	$< 10^{-8}$
Sand and Gravel	Foundation	135	0	35	$> 10^{-3}$
Random Fill	Embankment	130	0	25	?
Impervious Fill	Embankment	135	0	28	$< 10^{-4}$
Gravel Fill & Bedding	Embankment	130	0	30	10^{-3} to 10^{-2}
Stone Protection	Embankment	120	0	35	$> 10^{-2}$
Stone Bedding	Embankment	120	0	40	$> 10^{-2}$
Sand	Embankment	125	0	28	10^{-3} to 10^{-2}
Silty Sand	Embankment	125	0	28	$< 10^{-4}$
Granular Fill	Embankment	130	0	28	10^{-3} to 10^{-2}

Note: Design values were estimated based on laboratory and exploration log data collected from other projects in the immediate vicinity, data from similar projects in the Boston Metropolitan area, and experience with similar materials.



LYNN BEACH
N
LYNN
Nahant Beach
DIKES AND WALLS
LYNN HARBOR
SAUGUS
TIDAL FLOODGATES
NAHANT
SHUTE BK.
RIVER
POINT OF PINES
EAST SAUGUS
Railroad
WALL, REVETMENT DUNES & BEACH
PROTECT ESTUARY STORAGE
PINES RIVER
PONDING AREA &WALL
Marsh
I-95 Fill
SAUGUS
BROAD SOUND
B & M
1A
Revere Beach
CREATE CLAM FLAT
MAINTAIN EXISTING SEAWALL & BEACH
ATLANTIC OCEAN
1
107
MALDEN
LINDEN BK.
PARK DIKE
Northgate
99
ROUGHANS POINT
REVERE
TOWN LINE BK.
TIDE GATE
1
SALES CR.
BELLE ISLE
Broadway
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
PS
DES. BY
PS
DR. BY
CK. BY
GENERAL PLAN
1 - MILE
GEOTECH. ENG. BR.
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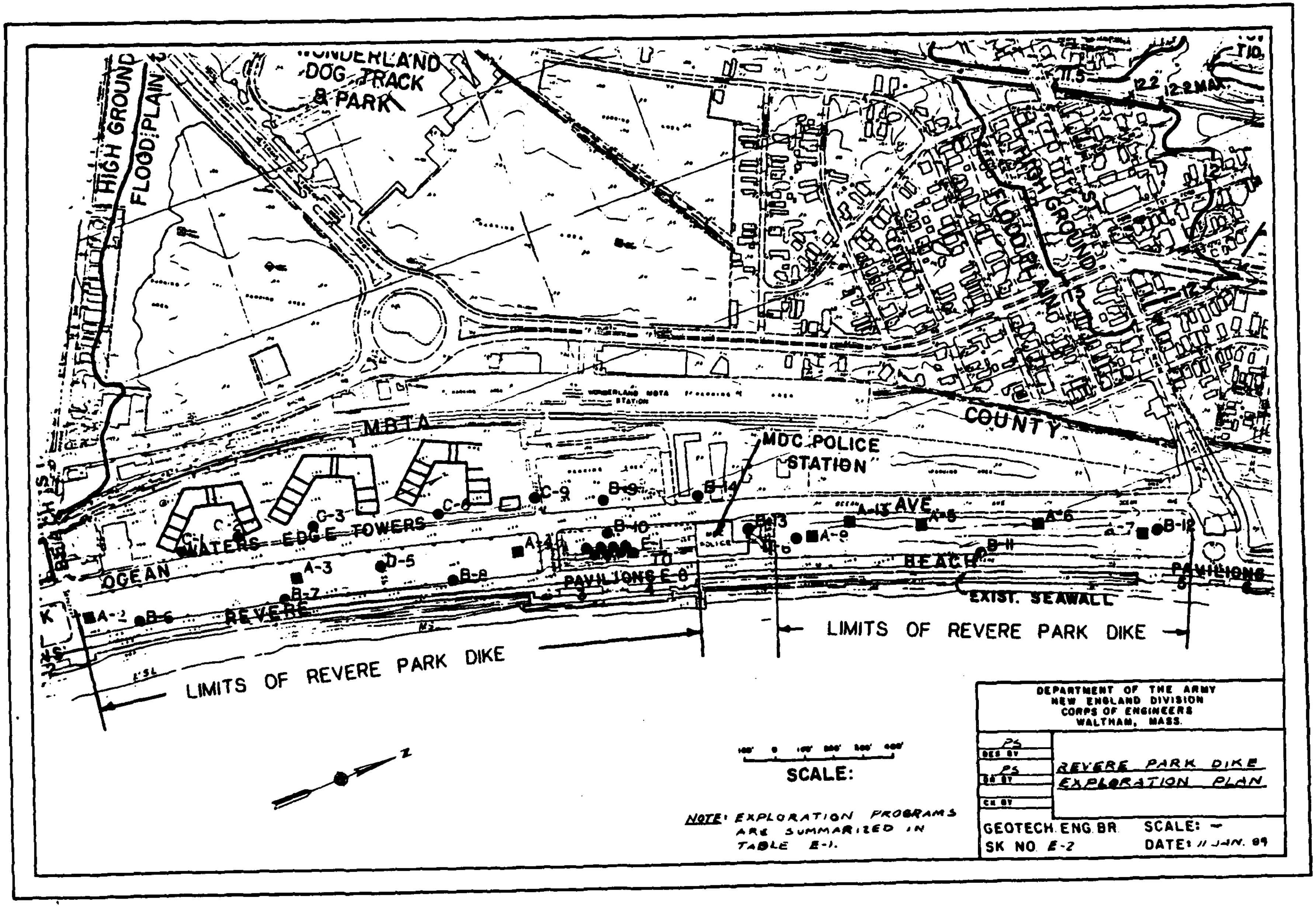
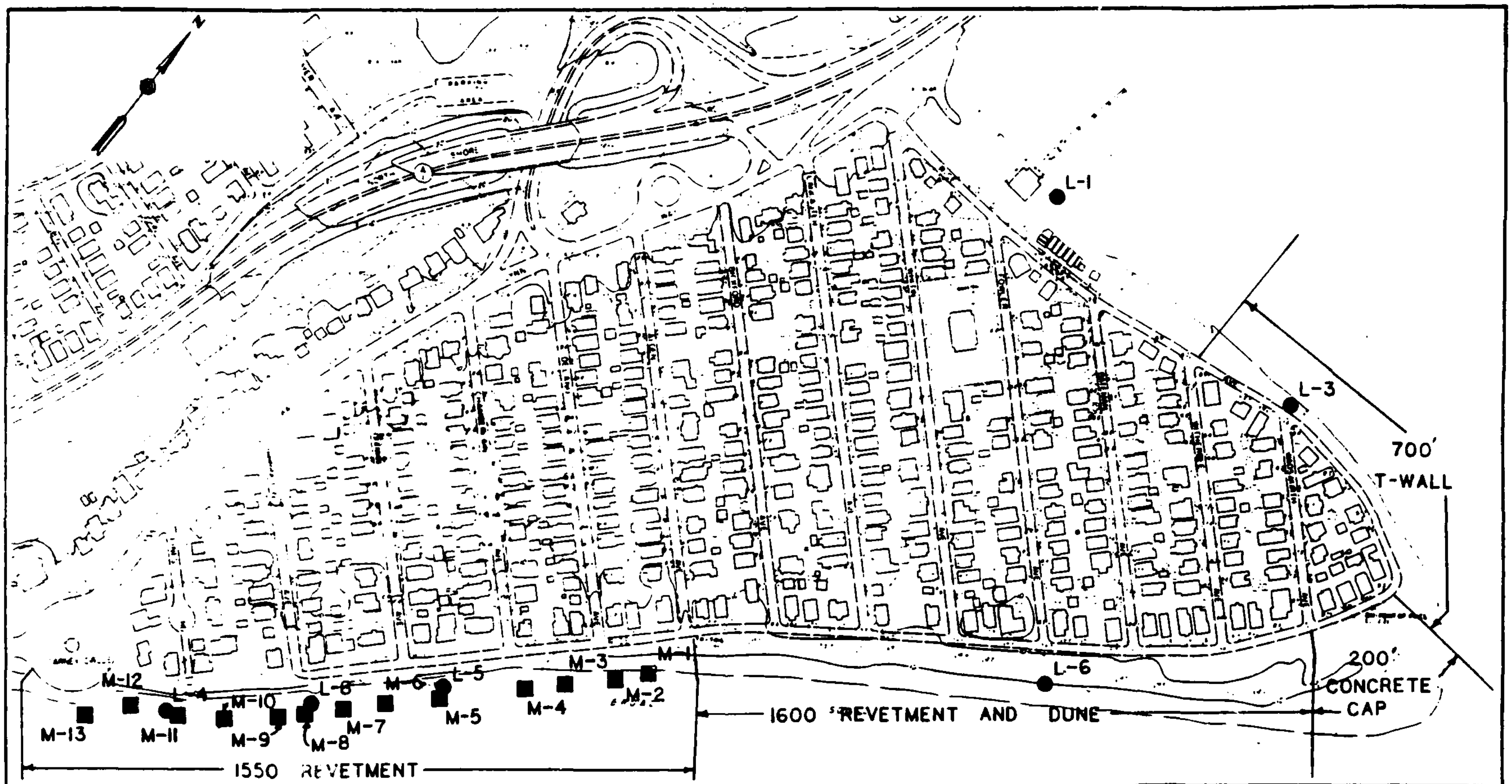
DATE: 2 MAR 89



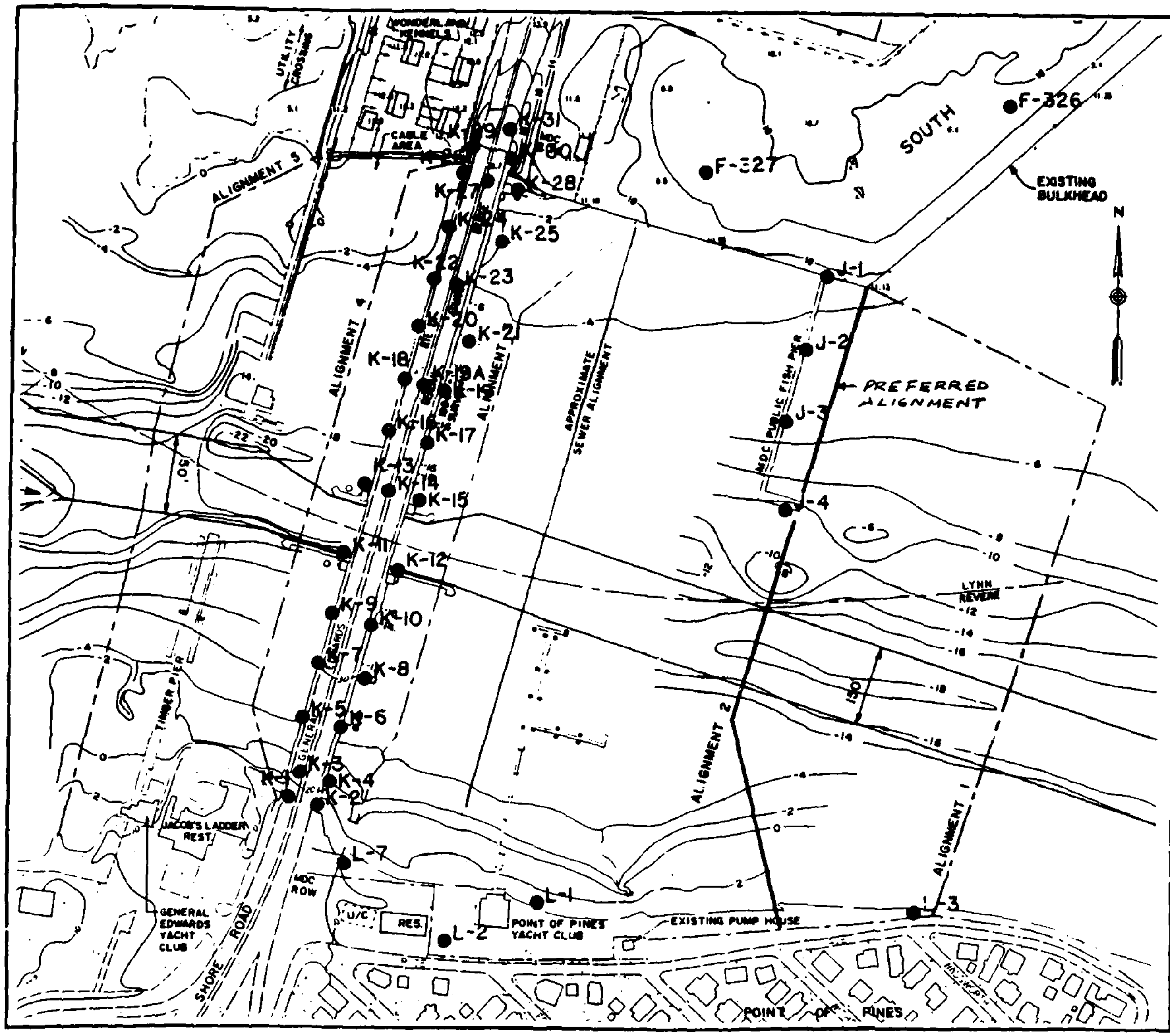
WONDERLAND DOG TRACK & PARK
HIGH GROUND
FLOOD PLAIN
FLOOD PLAIN
HIGH GROUND
COUNTY
MBTA
WONDERLAND MBTA STATION
MDC POLICE STATION
WATERS EDGE TOWERS
OCEAN
AVE
REVERE
BEACH
PAVILIONS
EXIST. SEAWALL
A-2
B-6
A-3
B-7
D-5
B-8
C-1
C-2
C-3
C-6
C-9
B-9
B-10
B-14
B-13
A-9
A-13
A-8
A-6
A-7
B-12
B-11
E-1
TO
E-8
LIMITS OF REVERE PARK DIKE
LIMITS OF REVERE PARK DIKE
N
SCALE:
NOTE: EXPLORATION PROGRAMS ARE SUMMARIZED IN TABLE E-1.
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
DES BY PS
DR BY PS
CH BY
REVERE PARK DIKE
EXPLORATION PLAN
GEOTECH. ENG. BR.
SCALE: —
SK NO. E-2
DATE: 11 JAN. 89



NOTE: EXPLORATION PROGRAMS ARE SUMMARIZED IN TABLE E-1.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES BY PS	POINT OF PINES
DR BY PS	EXPLORATION PLAN
CH BY	
GEOTECH. ENG BR.	SCALE: —
SK NO. E-3	DATE: 11 JAN. 89

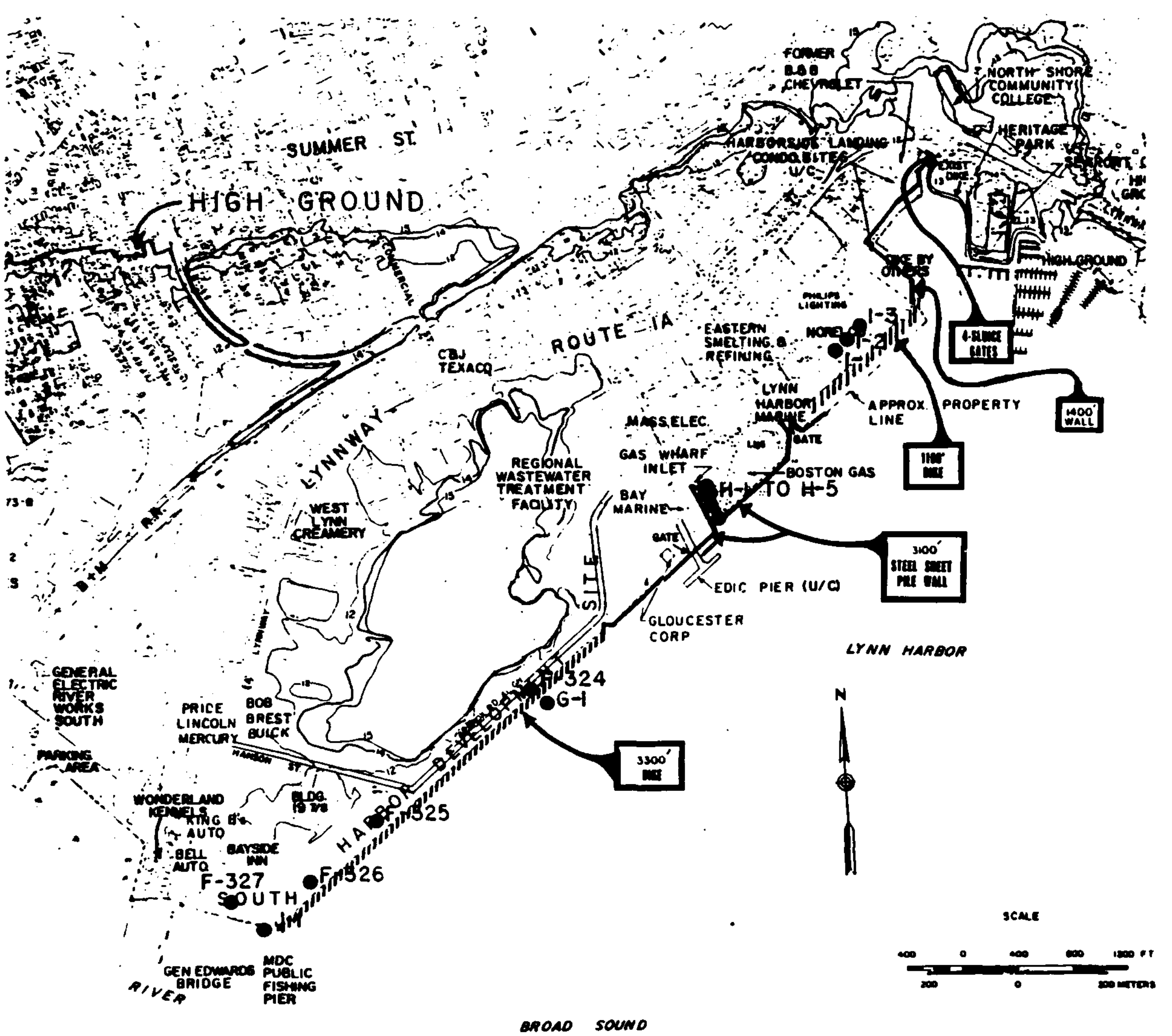


NOTE: EXPLORATION PROGRAMS ARE SUMMARIZED IN TABLE E-1.

SCALE

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

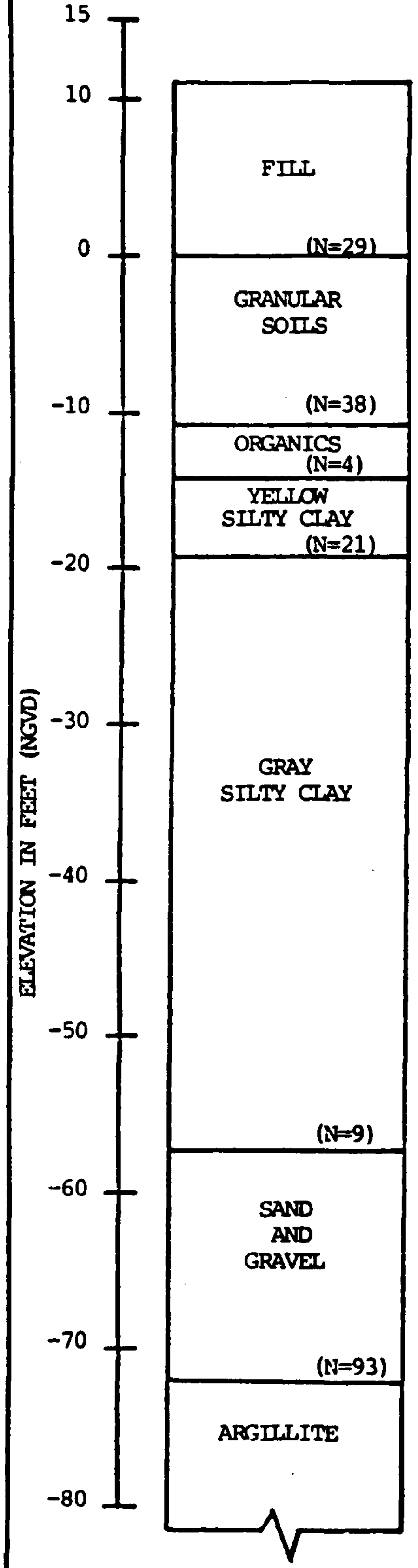
DES BY: PS	SAUGUS RIVER FLOODGATE EXPLORATION PLAN
DR BY: PS	
CK BY	
GEOTECH. ENG BR.	SCALE –
SK NO. E-4	DATE: 11 JAN 89



NOTE: EXPLORATION PROGRAMS ARE SUMMARIZED IN TABLE E-1.

LEGEND

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	
DES BY PS	LYNN DIKES AND WALLS EXPLORATION PLAN
DR BY PS	
CK BY	
GEOTECH ENG BR	SCALE –
SK NO E-5	DATE 11 JAN 89



NOTE:

The typical soil profile is intended to convey trends in subsurface conditions. It is based on 32 widely spaced explorations. The boundaries between strata are average boundary elevations and vary considerably between individual explorations. Standard penetration test values are averages for a particular stratum and may vary considerably within the stratum.

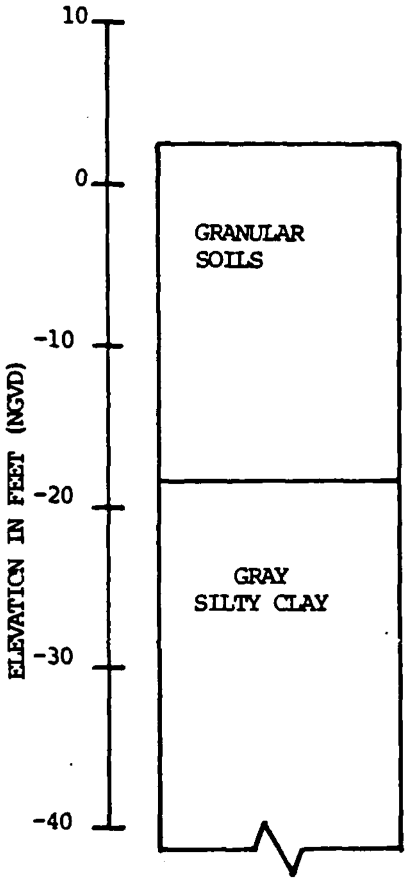
LEGEND:

(N=5) - "N" denotes standard penetration resistance in blows/foot.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PS DES. BY	REVERE PARK DIKE TYPICAL PROFILE
PS DR. BY	
CK. BY	

GEOTECH. ENG. BR. SCALE: -
SK. NO. E-6 DATE: 11 JAN 89

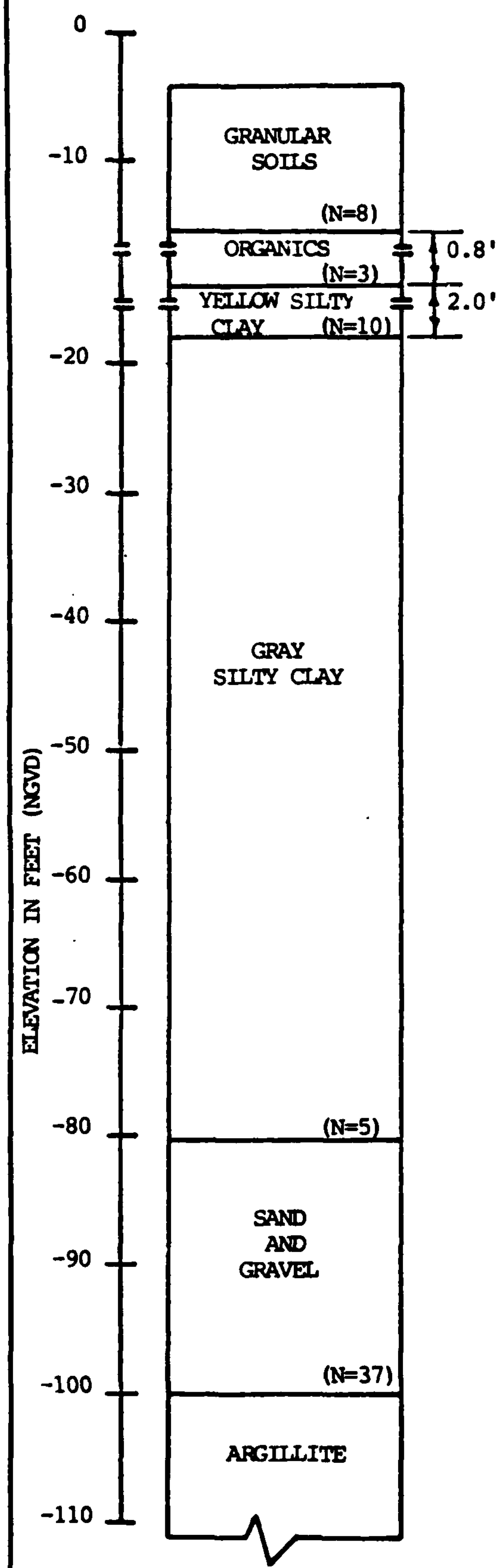


NOTE:

The typical soil profile is intended to convey trends in subsurface conditions. It is based on 19 widely spaced explorations. The boundaries between strata are average boundary elevations and vary considerably between individual explorations. Standard penetration tests were not performed in any of the explorations.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PS DES. BY	POINT OF PINES
PS DR. BY	TYPICAL PROFILE
CK. BY	
GEOTECH. ENG. BR.	SCALE: —
SK. NO. E-7	DATE: 11 JAN 89



NOTE:

The typical soil profile is intended to convey trends in subsurface conditions. It is based on 42 widely spaced explorations. The boundaries between strata are average boundary elevations and vary considerably between individual explorations. Standard penetration test values are averages for a particular stratu and may vary considerably within the stratum.

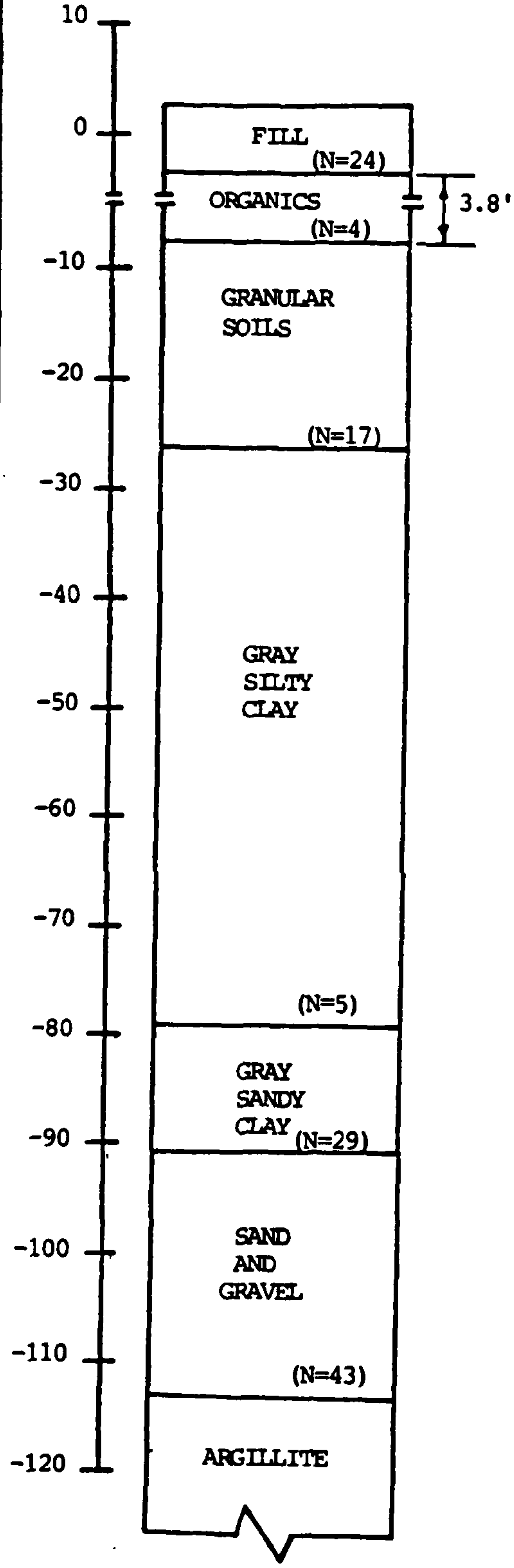
LEGEND:

(N=5) - "N" denotes standard penetration resistance in blows/foot.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PS DES. BY	SAUGUS RIVER FLOODGATE
PS DR. BY	TYPICAL PROFILE
CK. BY	

GEOTECH. ENG. BR. SCALE: –
SK. NO. E-8 DATE: 11 JAN. 89



NOTE:

The typical soil profile is intended to convey trends in subsurface conditions. It is based on 13 widely spaced explorations. The boundaries between strata are average boundary elevations and vary considerably between individual explorations. Standard penetration test values are averages for a particular stratum and may vary considerably within the stratum.

LEGEND:

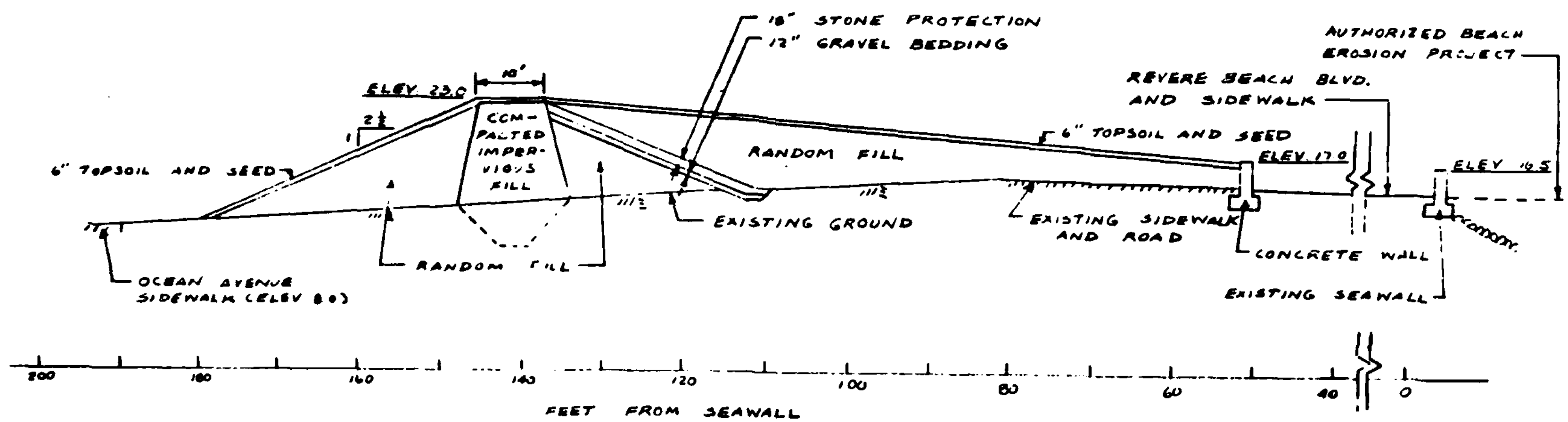
(N=5) - "N" denotes standard penetration resistance in blows/foot.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PS DES. BY	LYNN DIKES AND WALLS TYPICAL PROFILE
PS DR. BY	
CK. BY	

GEOTECH. ENG. BR. SCALE: —

SK. NO. E-9 DATE: 11 JAN 89

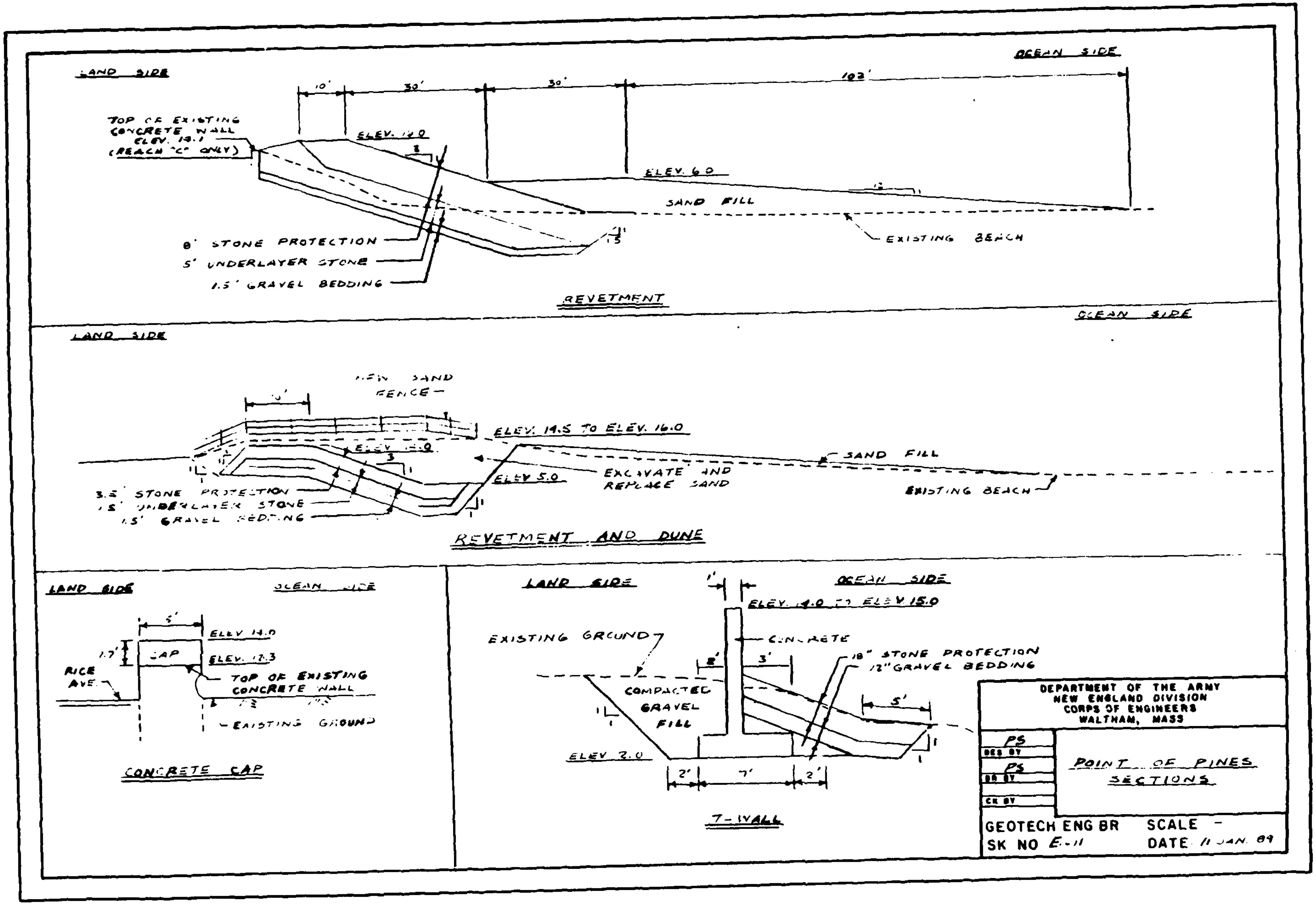


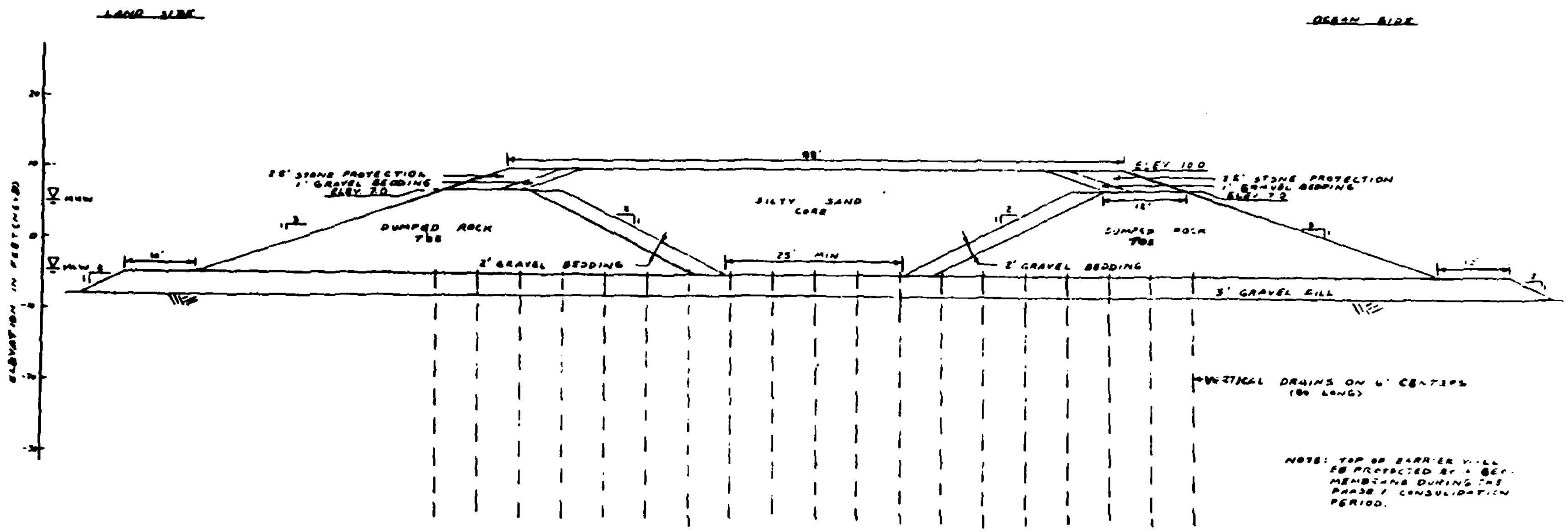
REVERE PARK DIKE

NOTES:

1. M.D.C. WILL CONSTRUCT THE CONCRETE WALL.
2. RANDOM FILL WILL BE OBTAINED FROM EXCAVATIONS REQUIRED FOR OTHER PROJECT FEATURES. THE LARGE SECTION IS NEEDED FOR DRAINAGE.

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS	
PS DES BY PS DR BY CH BY	REVERE PARK DIKE SECTION
GEOTECH ENG. BR SK. NO E-10	SCALE – DATE 11 JAN. 89


LAND SIDE
OCEAN SIDE
10'
30'
30'
102'
TOP OF EXISTING CONCRETE WALL ELEV. 13.1 (REACH "C" ONLY)
ELEV. 14.0
ELEV. 6.0
SAND FILL
EXISTING BEACH
8' STONE PROTECTION
5' UNDERLAYER STONE
1.5' GRAVEL BEDDING
REVETMENT
LAND SIDE
OCEAN SIDE
NEW SAND FENCE
ELEV. 14.5 TO ELEV. 16.0
SAND FILL
ELEV 5.0
EXCAVATE AND REPLACE SAND
EXISTING BEACH
3.5' STONE PROTECTION
1.5' UNDERLAYER STONE
1.5' GRAVEL BEDDING
REVETMENT AND DUNE
LAND SIDE
OCEAN SIDE
5'
ELEV 14.0
1.7'
CAP
ELEV. 12.3
RICE AVE.
TOP OF EXISTING CONCRETE WALL
EXISTING GROUND
CONCRETE CAP
LAND SIDE
OCEAN SIDE
1'
ELEV. 14.0 TO ELEV 15.0
EXISTING GROUND
CONCRETE
3'
18" STONE PROTECTION
12" GRAVEL BEDDING
COMPACTED GRAVEL FILL
5'
ELEV 2.0
2'
7'
2'
T-WALL
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS
PS
DES BY
PS
DR BY
CK BY
POINT OF PINES
SECTIONS
GEOTECH ENG BR
SCALE -
SK NO E-11
DATE 11 JAN. 89



SAUGUS RIVER FLOODGATE

OPTION I - PHASE I

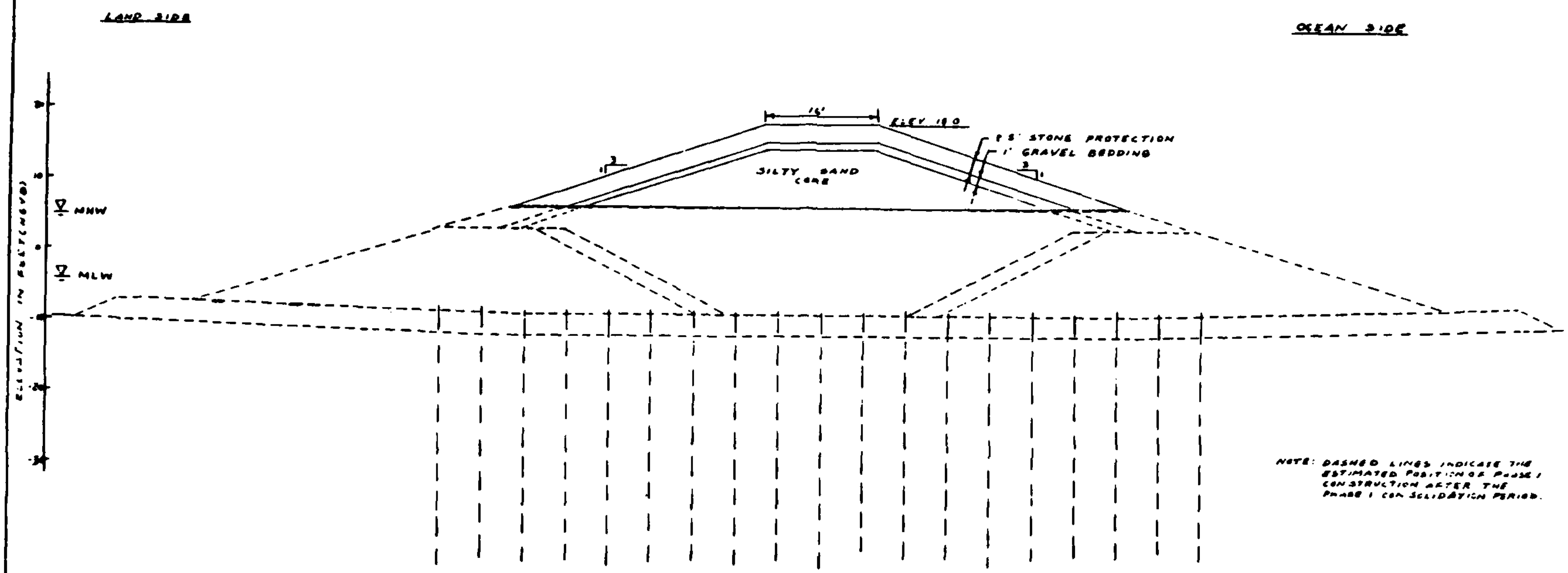
PREFERRED OPTION

SCALE

10' 0' 10' 20'

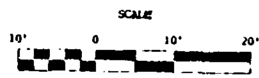
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

PS DES BY PS DR BY CK BY	SAUGUS RIVER FLOODGATE SECTION OPTION I - PHASE I
GEOTECH ENG BR SK NO E-12	SCALE - DATE 11 JAN 89



SAUGUS RIVER FLOODGATE
OPTION 1 - PHASE 2
PREFERRED OPTION

NOTE:
TOP ELEVATION EQUALS DESIGN STILLWATER LEVEL PLUS FREEBOARD FOR HYDRAULIC, HYDROLOGIC, AND GEOTECHNICAL (SETTLEMENT) CONSIDERATIONS.

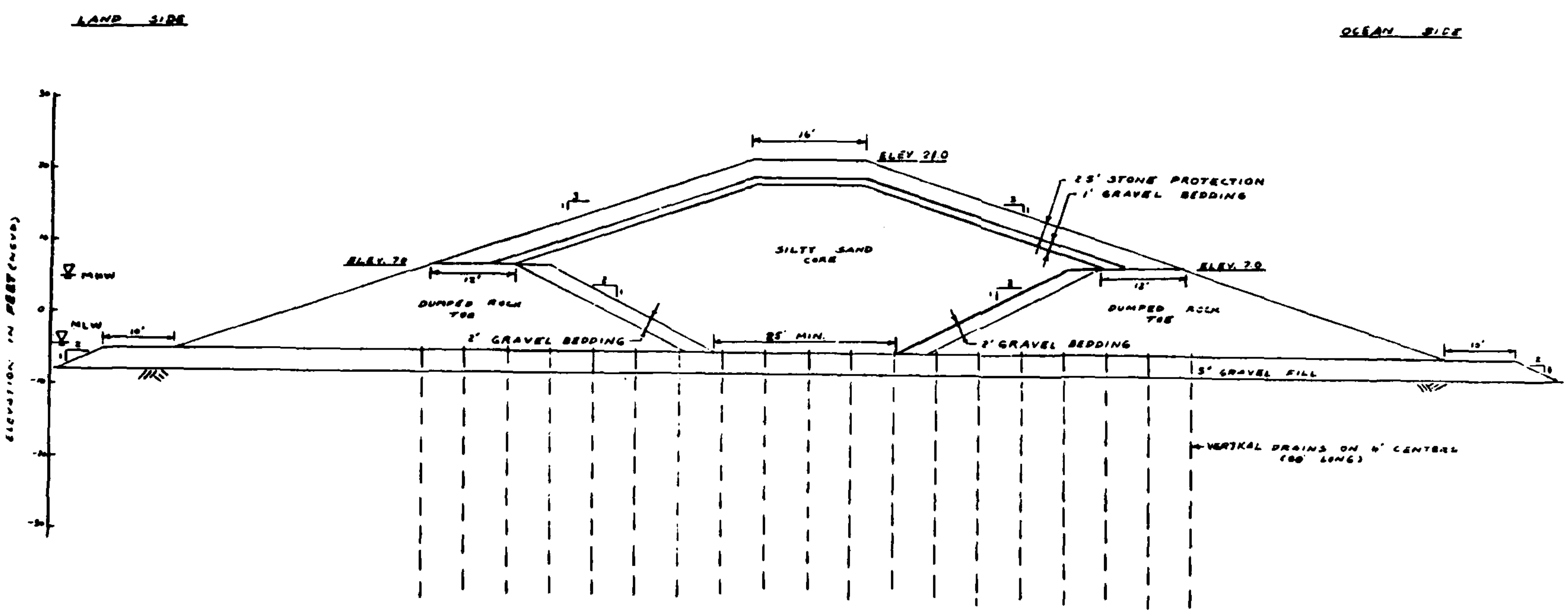


DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

DES BY PS
DR BY PS
CK BY

SAUGUS RIVER FLOODGATE
SECTION
OPTION 1 - PHASE 2

GEOTECH ENG BR SCALE -
SK NO E-13 DATE 11 JAN 81



SAUGUS RIVER FLOODGATE
OPTION 2
ALTERNATE OPTION

NOTE
TOP ELEVATION EQUALS DESIGN STILLWATER LEVEL PLUS FREEBOARD FOR HYDRAULIC, HYDROLOGIC, AND GEOTECHNICAL (SETTLEMENT) CONSIDERATIONS.

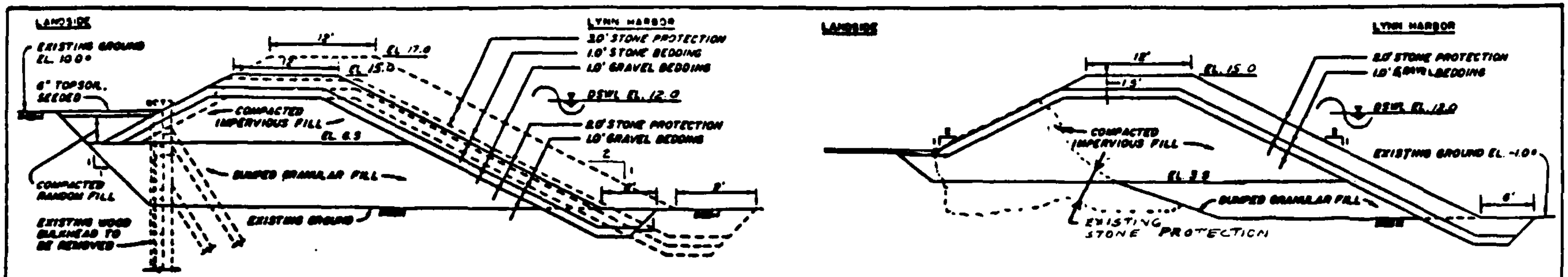
SCALE
10' 0' 10' 20'

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

DES BY PS
DR BY PS
CK BY

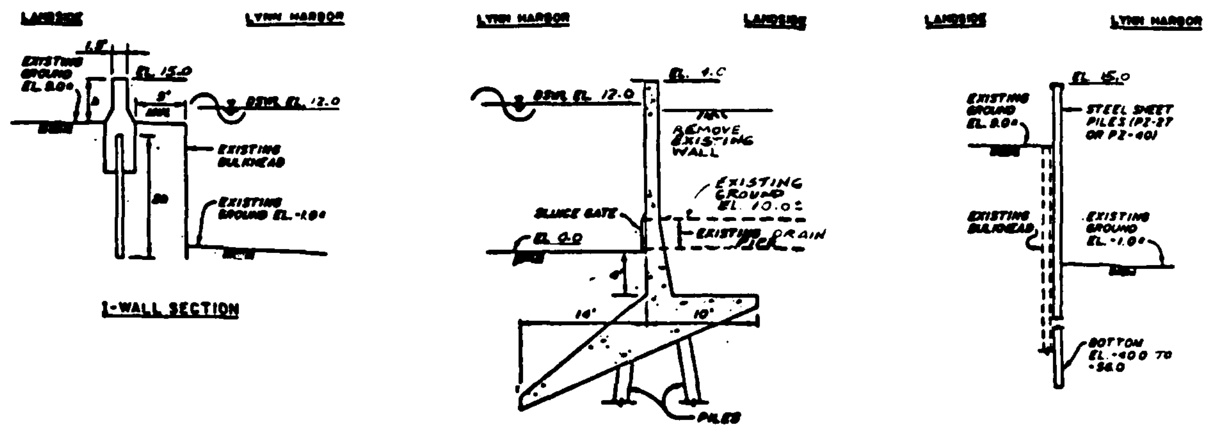
SAUGUS RIVER FLOODGATE
SECTION
OPTION 2

GEOTECH ENG BR SCALE -
SK NO E-14 DATE 11 JAN 89



NOTES:
1. DASHED LINES DEPICT MAXIMUM SECTION ALONG EXISTING WOOD BULKHEAD.
2. SOLID LINES DEPICT MINIMUM SECTION ALONG EXISTING WOOD BULKHEAD.

DIKE SECTIONS



I-WALL SECTION

T-WALL SECTION

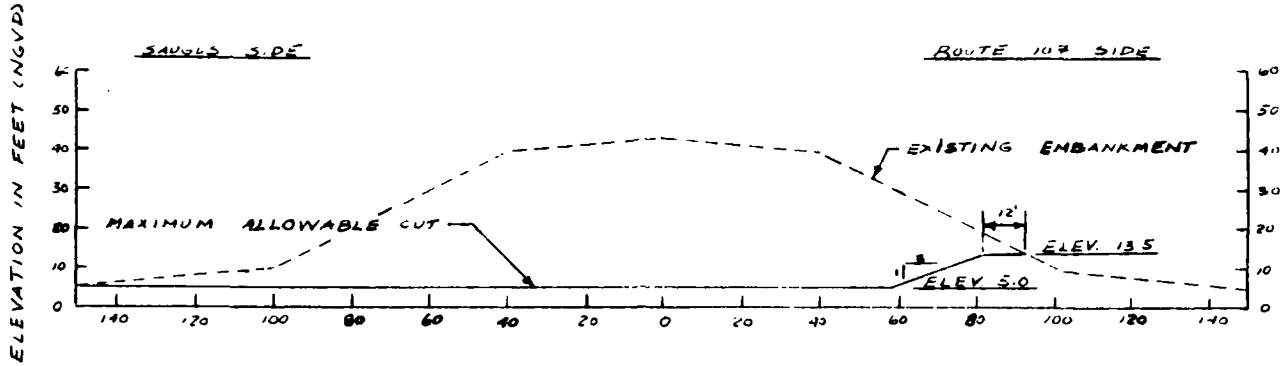
STEEL SHEET PILE WALL SECTION

WALL SECTIONS

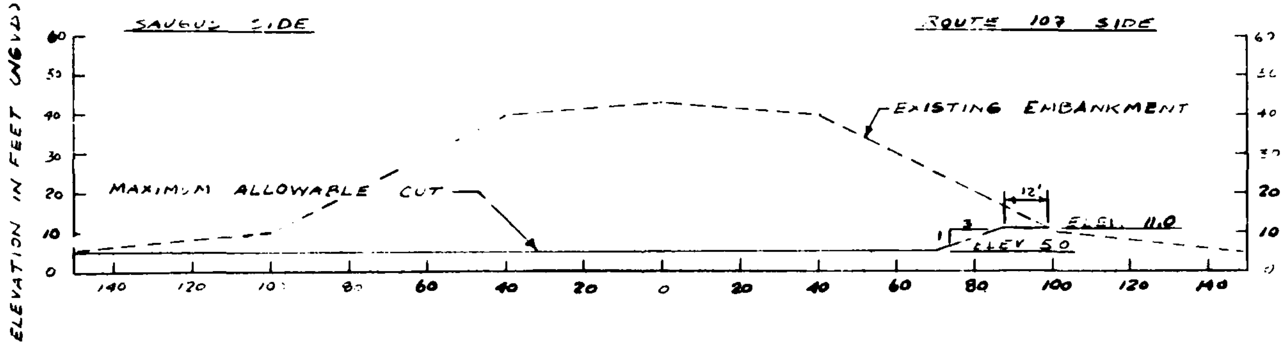
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

PS DES BY	LYNN DIKES AND WALLS SECTIONS
PS DR BY	
CK BY	

GEOTECH ENG BR SCALE –
SK NO E-15 DATE 11 JAN 89



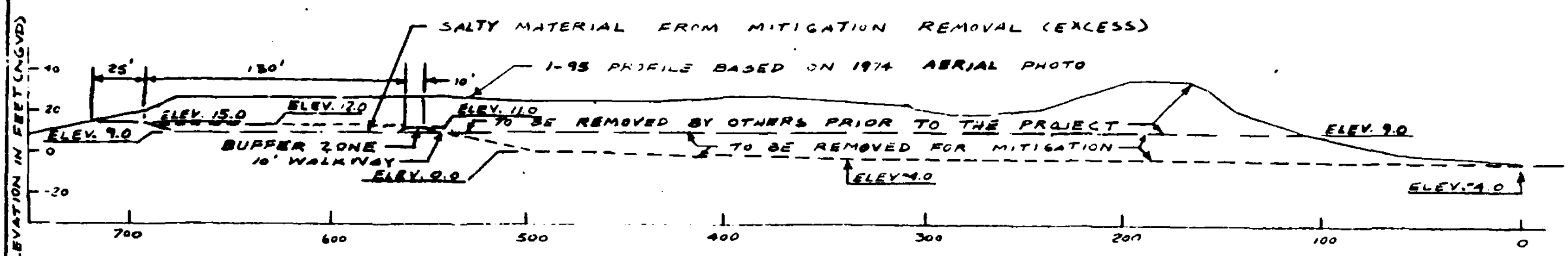
1-95 EMBANKMENT WITHOUT REGIONAL PLAN



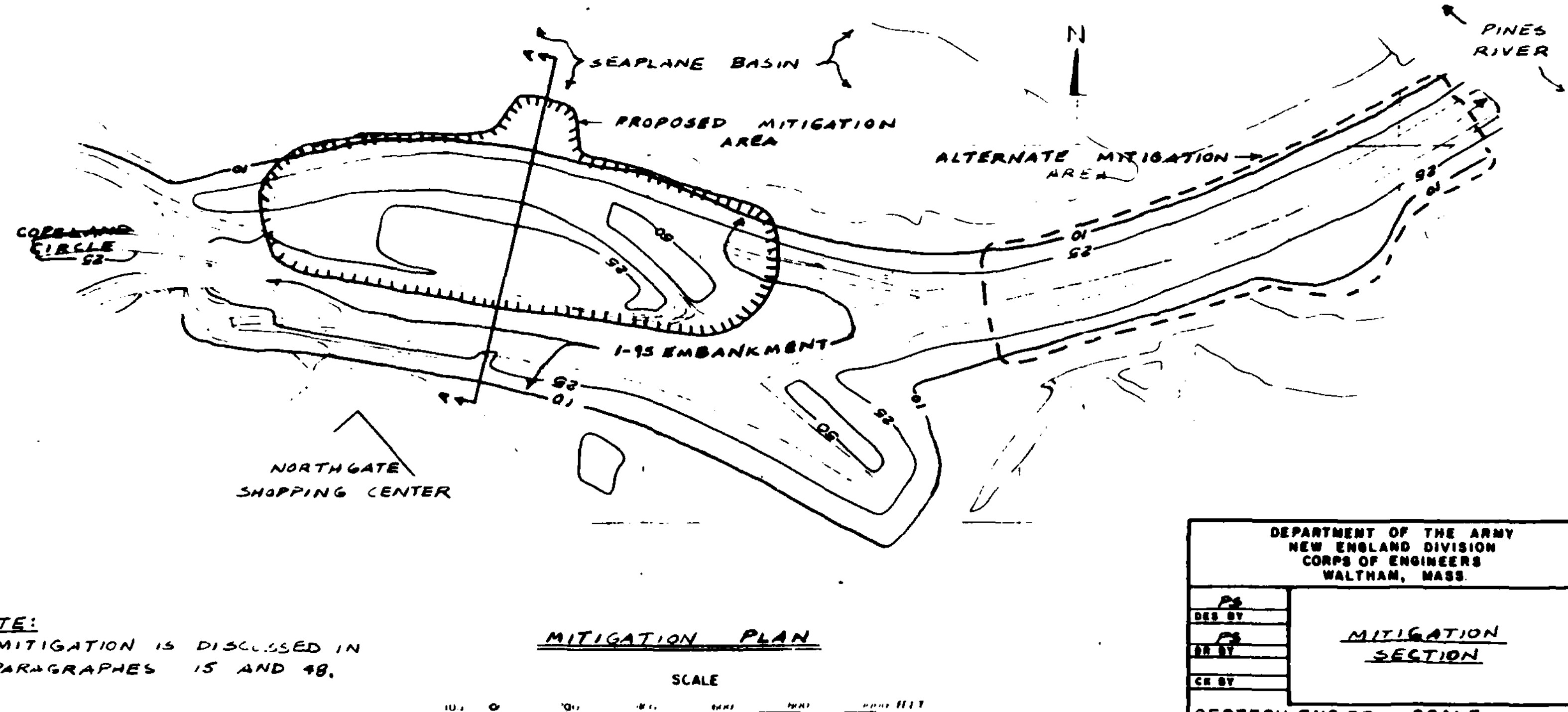
1-95 EMBANKMENT WITH REGIONAL PLAN

NOTE:
AN EXPLANATION FOR THE MAXIMUM ALLOWABLE CUT IS PRESENTED IN PARAGRAPH 47.

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	
PS DES BY PS DR BY CH. BY	1-95 SECTION
GEOTECH ENG BR SK NO E-16	SCALE – DATE 11 JAN 89



MITIGATION SECTION A-A



MITIGATION PLAN

SCALE

NOTE:
MITIGATION IS DISCUSSED IN PARAGRAPHES 15 AND 48.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES BY PS
DR BY PS
CK BY

MITIGATION SECTION

GEOTECH ENG BR SCALE -
SK NO E-17 DATE 11 JAN 89

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254-9149

SAUGUS RIVER AND TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY
LYNN, MALDEN, REVERE AND
SAUGUS, MASSACHUSETTS

REAL ESTATE
APPENDIX F

PRELIMINARY ESTIMATE
OF
REAL ESTATE COSTS

PREPARED BY: Edward J. Fallon
EDWARD J. FALLON
Review Appraiser

REVIEWED
&
APPROVED BY: William D. Brown, Jr.
WILLIAM D. BROWN, JR.
Chief, Appraisal Branch

JUNE 1989

Table of Contents

Addenda

PURPOSE

The purpose of this report is to estimate the Preliminary Real Estate costs associated with flood protection regarding SENE studies for implementation of a regional floodgate located at the mouth of the Saugus River in the cities of Revere and Lynn Massachusetts.

INSPECTION OF THE REAL ESTATE

The properties within the study areas were viewed in the field during the summer and winter of 1988, by this Appraiser.

LOCATION

The subject area is located in the Northeasterly section of Massachusetts, in the communities of Revere and Lynn, within the Counties of Suffolk and Essex.

SCOPE

The proposed floodgate will be located across the Saugus River, tying into the respective lands that lie adjacent to the river. Along with the floodgate stone revetments following the present bulkhead alignment that traverses Lynn Harbor will be necessary as well as, a combination of rock revetments and walls along Rice Avenue up to and including Carey Circle. In addition to these areas the M.D.C.Park Dike, located along Revere Beach Boulevard, a tide gate at Sales Creek and approximately 14± acres of tidal marsh for mitigation purposes will also be required.

Five alignments will be addressed with separate estimates for each.

By implementing this regional plan (a floodgate) about four communities, Revere, Lynn, Saugus and a very small portion of Malden will be protected against damages caused by a Northeaster type storm.

This report relates to the SPN (Standard Project Northeaster) which necessitates acquisition of permanent and temporary easement interests for purposes of construction and maintenance of a tidal barrier, dikes, concrete gravity and I-walls, and rock revetments.

Another aspect of the proposed project is the protection of the Estuary which will be used as a ponding or storage area during periods when the floodgates are closed. Present local ordinances and state statutes are adequate to protect the integrity of the estuary. Because of these regulations I have not included the cost of acquisition in any of the proposed Alignments but have included an estimate on page F-14.

DESCRIPTION OF PROJECT AREA

City of Revere

The City of Revere is located on the Massachusetts coast about two miles northeast of the City of Boston. About one-fifth of the area is a salt marsh adjacent to the Pines River Estuary, and about one-third of the city, including the marsh area, is below elevation 10 feet, mean sea level. The remainder of the city is gently rolling with a few steep hills, the highest elevation being at the reservoir on Fenno's Hill at about 192 feet above mean sea level. Most of the land above 10 feet mean sea level is fully developed. Any future development would be at the expense of existing uses. The population of the city is about 43,000, and on peak summer days more than 20,000 people visit the 3-1 /2 miles of Revere Beach for recreational purposes.

City of Lynn

City of Lynn is located in Essex County in the eastern section of Massachusetts on the northern shore of Massachusetts Bay, bordered by Saugus and Lynnfield on the west, Saugus River on the southwest, Peabody and Salem on the north, Swampscott and the Atlantic Ocean on the east and Nahant and Revere on the south. It is 11 miles from Boston. The population is about 79,000 in an area of approximately 11.21 square miles. During the 1970-1980 decade, the population decreased by 11,823 or 13.1%. The city was industrial early in its history with the first iron smelting plant in America being established there in 1643. Also, it was a famous shoe city. Today, Lynn is a diversified industrial center.

Rail and bus facilities are available in Lynn. The Mass. Bay Transportation Authority assures this area of adequate mass transportation. The Boston and Maine Railroad serves this area. The public roads and highways are in good condition; the principal highways serving the Lynn area are state Rts. 107 and 129. Logan International Airport is about 10 miles away.

City of Saugus

Saugus is a city of 25,000 persons; it serves as the gateway to Boston's North Shore and is 10 miles from Boston. It is bordered on the south by Revere, southeast by the Atlantic Ocean, Melrose and Wakefield on the southwest, Lynnfield on the northwest and Lynn on the north.

Saugus was originally a farming community; it then changed to industry and manufacturing and today it is mostly residential. Saugus has an area of 10.5 square miles, and it has excellent schools. There are churches of all denominations in the town and large and small shopping centers.

State Rts. 129, C-1, and 107 enter and serve the town, as well as U.S. Rt. 1. Bus service is provided by the Massachusetts Bay Transportation Authority and Greyhound Bus Company. The Boston and Maine Railroad services the town; and Logan International Airport and the Port of Boston are 8 miles away.

DESCRIPTION OF PROJECT AREAS AND ALIGNMENTS

The areas which comprise the Floodgate Plan include the Floodgate Area, (Saugus River) Lynn Harbor, Point of Pines, M.D.C. Park Dike, 14± acre Mitigation area and Tide Gate at Sales Creek.

There follows a description of each area.

FLOODGATE AREA(S)

There are five alignments for the location of the Floodgates.

ALIGNMENT 1

Alignment one commences at the bulkhead on the Lynn side of the Saugus River about 700 feet easterly of the General Edwards Bridge, traverses in a generally southeasterly direction for approximately 600 feet thence turns and traverses in a southwesterly direction a distance of approximately 700 feet terminating at the wall on the northerly side of Rice Avenue adjacent to Wadsworth Avenue in the City of Revere.

ALIGNMENT 2

Alignment two commences at the bulkhead on the Lynn side of the Saugus River about 700 feet easterly of the General Edwards Bridge, traverses in a generally southerly direction for approximately 850 feet thence turns and traverses in a southeasterly direction a distance of approximately 400 feet terminating at the wall on the northerly side of Rice Avenue adjacent to Witherbee Avenue in the City of Revere.

NOTE: Alignments 1 and 2 include the Point of Pines area while Alignments 3,4 and 5 do not. Also not included in Alignments 1 and 2 is Reach "A" of the Lynn Harbor Alignment.

ALIGNMENT 3

Alignment 3 would be located approximately one hundred (100) feet easterly of the General Edwards Bridge, commencing at the bulkhead on the northerly side of the Saugus River adjacent to the northeasterly abutment of the General Edwards Bridge, and traversing in a general southerly direction a distance of approximately 1,350 feet, terminating in the southeasterly abutment of the bridge adjacent to the Point of Pines Yacht Club .

ALIGNMENT 4

Alignment 4 would be located approximately one hundred (100) feet westerly of the General Edwards Bridge, commencing at the northwesterly abutment of the General Edwards Bridge, and traversing in a general southerly direction a distance of approximately 1,320 feet, terminating in the southwesterly abutment of the bridge adjacent to the building (restaurant) formerly know as Jacob's Ladder.

ALIGNMENT 5

Alignment 5 would be located approximately four hundred eighty (480) feet westerly of the General Edwards Bridge, commencing at the northwesterly side of the General Electric saltwater intake pipe, and traversing in a general southwesterly direction a distance of approximately 520 feet, thence turns and traverse in a southerly direction a distance of approximately 1,000 feet terminating at the bulkhead of Fowler Marina Inc.

LYNN HARBOR AREA

NOTE: Reaches "A" through "D" follow the existing bulkhead alignment.

REACH "A"

Reach "A" commences at the easterly abutment of the General Edwards Bridge and traverses in an easterly direction along the bulkhead for a distance of approximately 700 feet, terminating at a dog leg in the bulkhead where Reach "B" begins.

REACHES "B" and "C"

Reach "B" commences at the dog-leg of the bulkhead and traverses in a general northeasterly direction a distance of approximately 1,800 feet to a point where it intersects with Reach "C" and continues in the same general direction a distance of approximately 1,500 feet to a point adjacent to the Gloucester Corporation, where it intersects with Reach "D". Both of these reaches follow the bulkhead alignment.

REACH "D"

Reach "D" is divided into four sections and is comprised of approximately 3,125 linear feet. "D1" commences at the intersection of Reach "C", follows the same direction for an approximate distance of 1,065 feet to the corner of the bulkhead of Bay Marine where "D2" commences and traverses along the following courses as stated in a northwesterly and southerly direction for 280, 30, 10, 30, and 370 feet respectively, terminating at the corner of the bulkhead of Boston Gas Company where "D3" intersects. "D3" follows the same alignment as the existing wall of Boston Gas for an approximate distance of 630 feet where it intersects with "D4". Then "D4" turns and traverses along the following courses and distances: northerly, 160 feet; northwesterly, 110 feet to the boat ramp and parking area where a 40 foot gate will have to be installed; then along Lynn Harbor Marine for 150 feet; thence turning and traversing in a northeasterly direction for approximately 160 feet, thence turns and traverses in a northwesterly direction approximately 130 feet where it intersects with Reach "E".

REACH "E" & "F"

Reach "E" traverses in a northeasterly direction for approximately 1,100 feet where it intersects with "F". Then "F" turns and traverses in a northeasterly direction for approximately 1,440 feet terminating at the Heritage Park retaining wall. These alignments follow the shoreline of Eastern Smelting & Refining Corporation, Norelco Lighting, Goodman and Trans Continental.

POINT OF PINES AREA

Reach "A" would commence on the westerly side of Carey Circle and would traverse in an easterly direction a distance of about 230 feet ending at Reach "B". A stone revetment at elevation 13.2 feet would be constructed throughout this reach.

Reach "B" commences at Reach "A's" termination and would continue to traverse in an easterly direction for a distance of about 1320 feet including Reaches "C" and "D" as well. A stone revetment at elevation 16.0 and 14.5 (D) feet would be constructed throughout these Reaches. Upon joining Reach "E" there is an area of transition from stone revetment to a stone revetment and sand dune, which continues in an easterly direction to Reach "F" a distance of about 1600 feet.

Reach "F" commences at the concrete wall at the easterly end of Rice Avenue and traverses about 200 feet at which point it turns and traverses in a northerly direction a distance of about 1035 feet, (400 feet for floodgate alignment #1 and 700 feet for floodgate alignment #2).

M.D.C. Park Dike & WALL

The M.D.C. Park Dike contains approximately 8.50± acres which is all of the land between Beach and Revere Streets and between Ocean Avenue and Revere Beach Boulevard, except for a block of land at the Beach Street end and that area where the M.D.C. Police Station is situated. A Dike is proposed for this area and will encompass virtually all of the acreage. The ponding area wall includes about 0.04± acres between the Boulevard and Route 1A (North Shore Road).

TIDAL GATE SALES CREEK

A Tidal Gate adjacent to the intersection of Revere Beach Parkway and North Shore Road and in Sales Creek is required and will require about .023 acres of abutting lands for access and maintenance purposes.

14+ ACRE SEAPLANE BASIN, CLAM FLAT MITIGATION AREA

Due to project impacts on shellfish resources, a mitigation area located at the Seaplane Basin containing approximately 14± acres is required.

In order to maintain the integrity of this area a dike surrounding the entire mitigation area will be constructed. Part of the area required for the dike will be used for permanent stockpiling of the salty sand material removed from between elevation 9.0 and -4.0.

GOVERNMENT OWNED FACILITIES

Section III of the Act of Congress approved 8 July 1958, (PL 85-500) authorized the protection, realteration, reconstruction, relocation or replacement of municipally-owned facilities. A preliminary inspection of the project areas indicated no Government owned facilities would be affected

RIGHTS TO BE ACQUIRED

Local interests will be required to provide all lands, easements and rights-of-way necessary for project purposes.

FEE AREAS

There are no known areas requiring fee acquisition at this time. However, if the parking area presently under easement to the M.D.C. (Metropolitan District Commission) and used in conjunction with the fishing pier is terminated, then fee acquisition of a one acre parcel would be necessary.

PERMANENT EASEMENT AREAS

Permanent easements for construction and maintenance purposes are necessary. Preliminary investigations indicate that after the imposition of the permanent easement interest, the highest and best use, at the present time, of the remainders of the properties affected will not be materially affected. However, it is historically known that the mere knowledge and existence of the imposition infers a restrictive aspect. Therefore, the cost to acquire the permanent easement interest would be equivalent to the underlying fee value since those uses would be for project purposes. However, lands would remain in their private ownerships to maintain conformity of their existing lot areas. The estimated costs for the permanent easement rights are predicated on the assumption that construction methods will be of the excavation and placement methods and would not adversely affect surface or near-surface improvements. If it is determined and found that selected methods of construction would cause damage to surface or near-surface improvements, then the estimated costs for easement rights would not remain valid and a new in-depth real estate study of the proposed taking would be required.

The permanent easement estimates vary from one alignment to another and will be shown under the estimate of real estate costs, by alignment and in the Addenda of this report.

TEMPORARY EASEMENTS

Temporary easements 35 to 50 feet wide, on either side of dikes, walls, barrier and all other areas requiring construction or excavation are necessary, where available, during the construction period as well as staging areas adjacent to the work site(s). The staging areas identified are for planning purposes only and are as follows: approximately one acre on the Lynn side adjacent to the General Edwards Bridge and along side the bulkhead. This area is identified for Barrier Alignments 1 thru 3. Alignments 4 and 5 could utilize the area of the former Wonderland Dog Kennels as well as an area at Gibson Park.

In lieu of repeating the requirements for each segment by area or reach, only the total area and value, will be shown under the estimate of real estate costs, by alignment and in the Addenda of this report.

The estimated values are based on comparable market data and reflect a fair rate of return for the use of the owners land for about one year, at 15% per annum. Actual estimates will be reflected in appraisals and may be higher or lower due to market and economic conditions or trends in the area at that time.

ACQUISITION COSTS

Acquisition costs will include costs for mapping, surveying, legal descriptions, title evidence, negotiations, closing and administrative costs for possible condemnations. The acquisition costs are based upon this office's experience in similar civil works projects in the general area and are estimated at $6,000.00 per ownership including the cost of appraisals.

RELOCATION COSTS

Public Law 91-646, Uniform Relocations Assistance Act of 1970, provided for uniform and equitable treatment of persons displaced from their homes, businesses, or farms by a Federally Assisted Program. It also established uniform and equitable land acquisitions policies for these projects. Included among the items under PL 91-646 are the following:

a. Moving Expenses
b. Relocation Allowance (Business)
c. Replacement Housing (Homeowners)
d. Replacement Housing (Tenants)
e. Relocation Advisory Services
f. Recording Fees
g. Transfer Taxes
h. Mortgage Prepayment Costs
i. Real Estate Tax Refunds (Pro-Rata)

Preliminary investigations indicate that none of the ownerships will require relocation assistance at this time. Should the existing preliminary taking lines be changed to include improvements, then the taking authority must certify that there will be available, in areas generally not less desirable and at rents/prices within the financial means of those that would be displaced, decent, safe and sanitary facilities, equal in number to the number of, and available to, such displaced persons who require such dwellings and reasonably accessible to their places of employment.

The ownerships affected by the permanent easement interests vary according to the plan and are reflected in the recapitulation of real estate costs. Therefore, an estimate of $ 200.00 per ownership is carried for planning purposes and is limited to expenses incidental to the transfer of real estate interests.

SEVERANCE DAMAGES

Severance damages usually occur when partial takings are acquired which restrict the remaining portion from full economic development. The severance damages are measured and estimated on the basis of a "Before" and "After" appraisal method and will reflect actual value loss incurred to the remainder as a result of partial acquisition. Detailed appraisals will reflect these losses.

Preliminary investigations indicate that two ownerships may be affected by Alignments 4 and 5, the restaurant (formerly Jacob's Ladder) at the bridge abutment and a portion of

Captain Fowlers Marina. To estimate what the damages might be at this time would be fruitless or near impossible due to a number of reasons, such as, the need for detailed plans depicting the limits of construction as well as the fact that both these areas are being scheduled for some type of condominium project in the future. Depending upon the type of project proposed it could or may have a severe impact on our proposed project.

PROTECTION AND ENHANCEMENT OF CULTURAL ENVIRONMENT

In accordance with instruction set forth in Teletype DA (DAEN) R 191306A, dated October 1971, Subject: "E011593, 13 May 1971, Protection and Enhancement of Cultural Environment"; a study has been made in the subject areas. The study revealed that no local, State, Federally owned nor Federally controlled property of historical significance would fall within the provisions of E011593.

CONTINGENCIES

A contingency allowance of 25 percent is considered to be reasonably adequate to provide for possible appreciation of property values from the time of this estimate to the acquisition date, for possible minor property line adjustments or for additional hidden ownerships which may be developed by refinement to taking lines, for adverse condemnation awards and to allow for practical and realistic negotiations.

WATER RIGHTS

Lands that would be acquired for project purposes may affect riparian interests. Upon selection of an option or plan and refinement of all alignments, an in-depth study of the ownerships affected would be conducted to determine any damage resulting from the proposed acquisition. However, actual damages would be reflected in the acquisition appraisals.

ZONING

The lands affected by the various plans are zoned for: residential, commercial, industrial, condominiums, wetlands and just about any other allowed or existing use within the respective zoning district.

HIGHEST AND BEST USE

The highest and best use of the affected properties is considered, in most cases, to be their present use.

EVALUATION AND CONCLUSION

The areas of study for the various plans are based upon preliminary Engineering Division and assessors plans.

All alignments for dikes, walls, excavation and any other components which make up the various elements of the proposed project, regarding real estate interests are subject to refinement prior to any proposed construction.

The values of lands and improvements within the study areas have been estimated by the market data or comparables sales approach. Local assessors, real estate brokers, appraisers and other knowledgeable persons were contacted to secure data during the valuation process. Numerous sales were analyzed and the upper value for each category of land and improvements were used in the final estimate(s) of value. (Primary unit values used were $1,500 per acre marsh/wetlands and $15 per square foot in the commercial area.)

There is no easy or simple way in which real estate sales can be mathematically reduced to a simple value indicator. Each transaction involves not only individual needs, wishes and wants of a particular buyer or seller at the time of sale but the properties themselves vary widely as to size, shape, frontage, exposure, location access, soil conditions and topography. We have used as the best common denominator the price per square foot and/or the price per acre with a full understanding that these unit values may be the best index but by no means can they reflect all problems for a given parcel, area, lot or community.

On the following pages are a recapitulation or real estate costs by Alignments.

ALIGNMENTS 1 & 2
INCLUDES LYNN HARBOR, POINT OF PINES, M.D.C. PARK DIKE, SALES CREEK TIDAL GATE, 14± ACRE MITIGATION AREA AND 1 ACRE PARKING AREA

Permanent Easements	Rounded to closest $1,000	
29.26± acres Private & Public Ownership	$ 1,795,000	
Temporary Easements		
24.67± acres Private & Public Ownership	$ 1,046,000	
Total Permanent & Temporary Easement Costs	$ 2,841,000	
Contingency- 25% of above	$ 710,250	
Total Estimated Easement Costs		$ 3,551,250
Relocation Assistance Costs		
15 Private & Public Ownerships @ $200		$ 3,000
Acquisition Costs		
15 Private & Public Ownerships @ $6,000		$ 90,000
Total Estimated Real Estate Costs		$ 3,644,250
	Call	$ 3,644,000

ALIGNMENT 3
INCLUDES LYNN HARBOR, M.D.C. PARK DIKE, PARK DIKE, SALES CREEK TIDAL GATE, 14± ACRE MITIGATION AREA AND 1 ACRE PARKING AREA

Permanent Easements	Rounded to closest $1,000	
25.26± acres Private & Public Ownership	$ 1,789,000	
Temporary Easements		
19.48± acres Private & Public Ownership	$ 1,021,000	
Total Permanent & Temporary Easement Costs	$ 2,810,000	
Contingency- 25% of above	$ 702,500	
Total Estimated Easement Costs		$ 3,512,500
Relocation Assistance Costs		
7 Private & Public Ownerships @ $200		$ 1,400
Acquisition Costs		
7 Private & Public Ownerships @ $6,000		$ 42,000
Total Estimated Real Estate Costs		$ 3,555,900
	Call	$ 3,556,000

ALIGNMENT 4
INCLUDES LYNN HARBOR, M.D.C. PARK DIKE, PARK DIKE, SALES CREEK TIDAL GATE, 14± ACRE MITIGATION AREA AND 1 ACRE PARKING AREA

Permanent Easements	Rounded to closest $1,000	
25.32± acres Private & Public Ownership	$ 1,922,000	
Temporary Easements		
20.48± acres Private & Public Ownership	$ 1,117,000	
Total Permanent & Temporary Easement Costs	$ 3,039,000	
Contingency- 25% of above	$ 759,750	
Total Estimated Easement Costs		$ 3,798,750
Relocation Assistance Costs		
7 Private & Public Ownerships @ $200		$ 1,400
Acquisition Costs		
7 Private & Public Ownerships @ $6,000		$ 42,000
Total Estimated Real Estate Costs		$ 3,842,150
	Call	$ 3,842,000

ALIGNMENT 5
INCLUDES LYNN HARBOR, M.D.C. PARK DIKE, PARK DIKE, SALES CREEK TIDAL GATE, 14± ACRE MITIGATION AREA AND 1 ACRE PARKING AREA

Permanent Easements	Rounded to closest $1,000	
25.39± acres Private & Public Ownership	$ 1,968,000	
Temporary Easements		
20.48± acres Private & Public Ownership	$ 1,117,000	
Total Permanent & Temporary Easement Costs	$ 3,085,000	
Contingency- 25% of above	$ 771,250	
Total Estimated Easement Costs		$ 3,856,250
Relocation Assistance Costs		
8 Private & Public Ownerships @ $200		$ 1,600
Acquisition Costs		
8 Private & Public Ownerships @ $6,000		$ 48,000
Total Estimated Real Estate Costs		$ 3,905,850
	Call	$ 3,906,000

ESTUARY (SALT MARSH) ACQUISITION

Permanent Easements or Fee 1650± acres Private & Public Ownership	$ 2,475,000	
Contingency- 25% of above	$ 618,750	
Total Estimated Easement or Fee Costs		$ 3,093,750
Relocation Assistance Costs 360 Private & Public Ownerships @ $200		$ 72,000
Acquisition Costs 360 Private & Public Ownerships @ $6,000		$ 2,160,000
Total Estimated Real Estate Costs		$ 5,325,750
Call		$ 5,326,000

ADDENDA

SAUGUS RIVER FLOODGATE

PERMANENT EASEMENTS

			ACRES	ESTIMATED VALUE
ALIGNMENTS 1 & 2				
	A;	Lynn Harbor	1.470	$ 968,625
	B;	Point of Pines	4.000	$ 6,000
	C;	Access	.152	$ 2,000
	D;	MDC Park Dike	8.540	$ 85,000
	E;	Parking Area	1.079	$ 705,000
	F;	Sales Creek	.023	$ 500
	G;	Mitigation Area	14.000	$ 28,000
			29.260	$1,795,125
ALIGNMENT 3				
	A;	Lynn Harbor	1.470	$ 968,625
	C;	Access	.152	$ 2,000
	D;	MDC Park Dike	8.540	$ 85,000
	E;	Parking Area	1.079	$ 705,000
	F;	Sales Creek	.023	$ 500
	G;	Mitigation Area	14.000	$ 28,000
			25.260	$1,789,125
ALIGNMENT 4				
	A;	Lynn Harbor	1.470	$ 968,625
	C;	Access	.207	$ 135,000
	D;	MDC Park Dike	8.540	$ 85,000
	E;	Parking Area	1.079	$ 705,000
	F;	Sales Creek	.023	$ 500
	G;	Mitigation Area	14.000	$ 28,000
			25.320	$1,922,125
ALIGNMENT 5				
	A;	Lynn Harbor	1.470	$ 968,625
	C;	Access	.276	$ 180,000
	D;	MDC Park Dike	8.540	$ 85,000
	E;	Parking Area	1.079	$ 705,000
	F;	Sales Creek	.023	$ 1,500
	G;	Mitigation Area	14.000	$ 28,000
			25.390	$1,968,125

SAUGUS RIVER FLOODGATE

TEMPORARY EASEMENTS

ALIGNMENTS 1 & 2

		ACRES	ESTIMATED VALUE	
A;	Lynn Harbor	9.730	$ 6,624,400	
B;	Point of Pines	4.940	$ 5,000	(NOMINAL)
C;	Barrier	.500	$ 326,700	
D;	MDC Park Dike	-0-	$ -0-	
E;	Parking Area	-0-	$ -0-	
F;	Sales Creek	.500	$ 500	
G;	Mitigation Area	9.000	$ 18,000	
		------	-----------	
		24.670	$ 6,974,600	
			x15%	

			$ 1,046,190	

ALIGNMENT 3

		ACRES	ESTIMATED VALUE
A;	Lynn Harbor	9.730	$ 6,624,400
C;	Barrier	.250	$ 163,500
D;	MDC Park Dike	-0-	$ -0-
E;	Parking Area	-0-	$ -0-
F;	Sales Creek	.500	$ 500
G;	Mitigation Area	9.000	$ 18,000
		------	-----------
		19.480	$ 6,806,400
			x15%

			$ 1,020,960

ALIGNMENT 4

		ACRES	ESTIMATED VALUE
A;	Lynn Harbor	9.730	$ 6,624,400
C;	Barrier	1.250	$ 803,400
D;	MDC Park Dike	-0-	$ -0-
E;	Parking Area	-0-	$ -0-
F;	Sales Creek	.500	$ 500
G;	Mitigation Area	9.000	$ 18,000
		------	-----------
		20.480	$ 7,446,300
			x15%

			$ 1,116,945

SAUGUS RIVER FLOODGATE

TEMPORARY EASEMENTS

ALIGNMENT 5

		ACRES	ESTIMATED VALUE
A;	Lynn Harbor	9.730	$ 6,624,400
C;	Barrier	1.250	$ 803,400
D;	MDC Park Dike	-0-	$ -0-
E;	Parking Area	-0-	$ -0-
F;	Sales Creek	.500	$ 500
G;	Mitigation Area	9.000	$ 18,000
		20.480	$ 7,446,300
			x15%
			$ 1,116,945